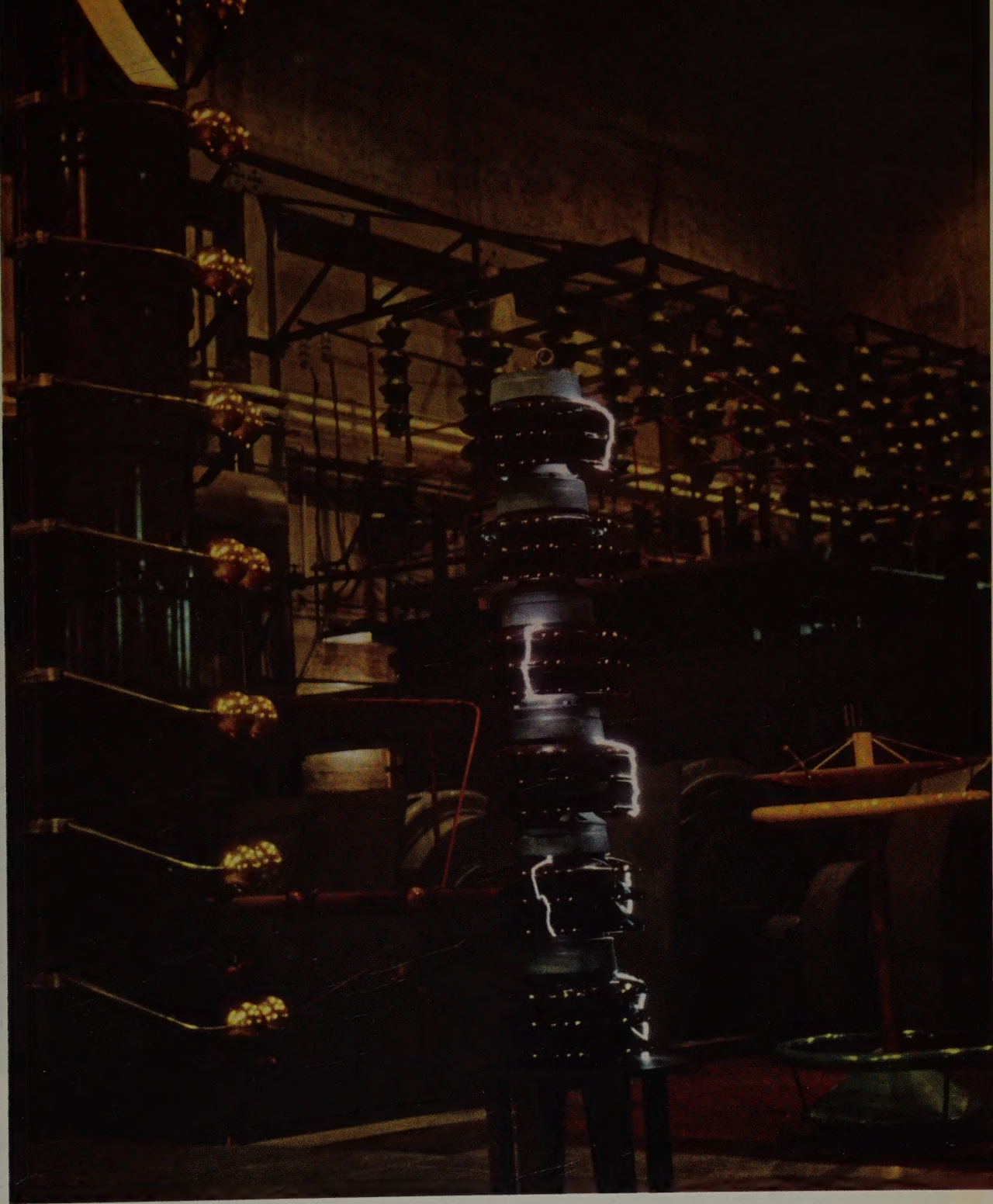




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6

Impulse flashover at 1,000 kV on a porcelain pillar insulator. The Asea High-voltage Laboratory, Ludvika. (F 514. Photo Gullers)



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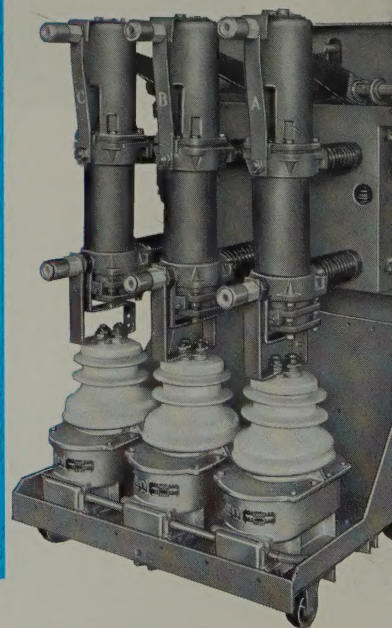
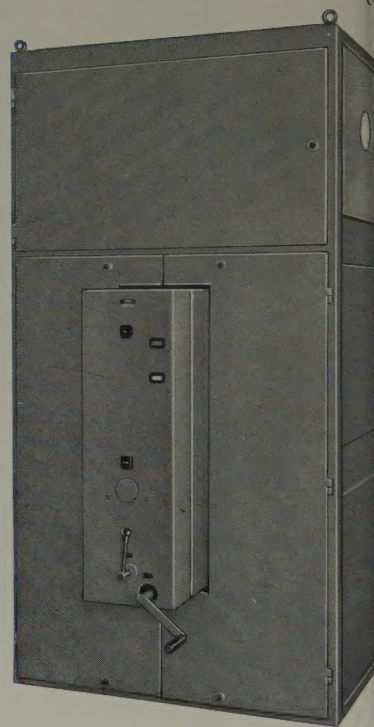
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THE MAINS-FREQUENCY INDUCTION HEATING OF LIGHT-ALLOY BILLETS

ve Sundberg, Furnace Department, Västerås

U.D.C. 621.365.5:621.78
Asea Reg. 664

The theoretical background to the induction heating of light-alloy billets and of the temperature conditions in the billets is given. Further, the design of the induction heater and the electrical plant, the regulation of the temperature and certain problems connected with operation are dealt with. Finally, an actual 2×300 kW, 50 c/s induction heating installation is described.

During recent years, the use of induction heaters for light-alloy billets has increased rapidly. They are mainly used in conjunction with the extrusion of profiles and tubes, but can also be used in connection with rolling, etc. The reasons for the popularity of the induction heaters are many:

More exact temperature control can be achieved than when using other types of heating. The heating temperature can rapidly and easily be reset for the various values desired for the different alloys. This is important since the series of billets of one and the same alloy are often short. Heating is rapid and the heater requires very little space. Because of the rapidity of heating, the actual work of deformation when extruding is less than would be the case with longer heating times.

5. Induction heaters can easily be combined with automatic feeding devices for the billets, thus reducing the need for personnel.
6. The induction heaters are ready to start heating operations immediately after they are switched on. Thus, no running-up time is required.

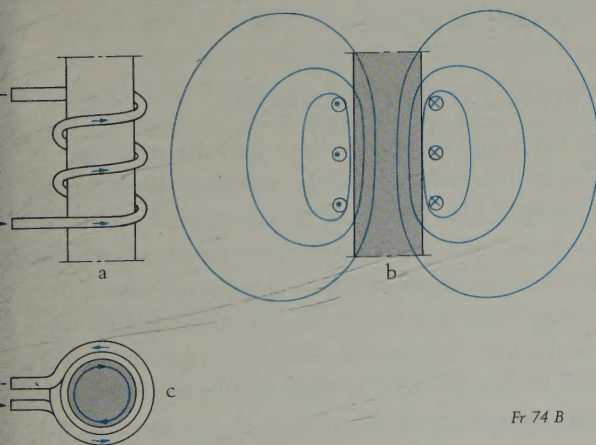
THE THEORY IN BRIEF

The theory of induction heating has been described previously [1-2]. Only those aspects of the theory which have a direct bearing on the problem in question have been included below.

When induction heating is to be carried out, the work-piece which is to be heated is placed in a coil which is energised by an alternating current. This induces in the work-piece what are known as eddy currents, which, because of the resistance in the work-piece, cause heating. Figs. 1 and 2 show the more usual types of heater.

The eddy currents flow primarily at the surface of the work-piece and the current density falls off towards the centre, largely in accordance with the equation

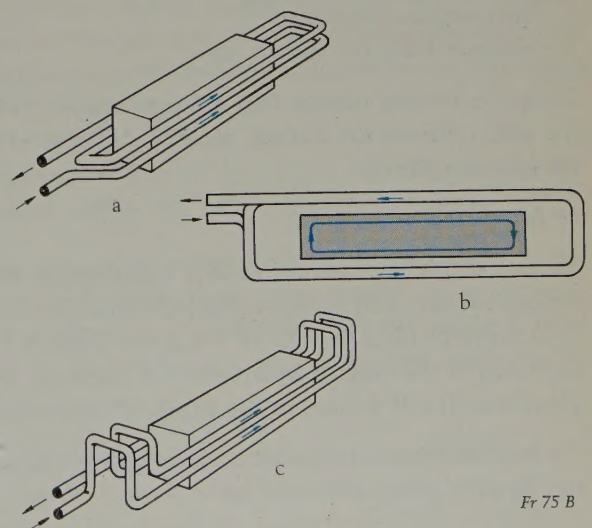
$$J = J_0 \cdot e^{-\alpha x} \quad \text{with } \alpha = 0.2 \pi \sqrt{\frac{f}{1,000} \cdot \frac{\mu_r}{\rho}}$$



Fr 74 B

- a) Heater with work-piece, seen from the side
- b) Diagram of the magnetic flux
- c) The heater seen from above with the directions of current flow indicated

Fig. 1. Axial-field heater.



Fr 75 B

- a and b) Simple form of heater
- c) Heater with coil ends bent upwards

Fig. 2. Cross-field heater.

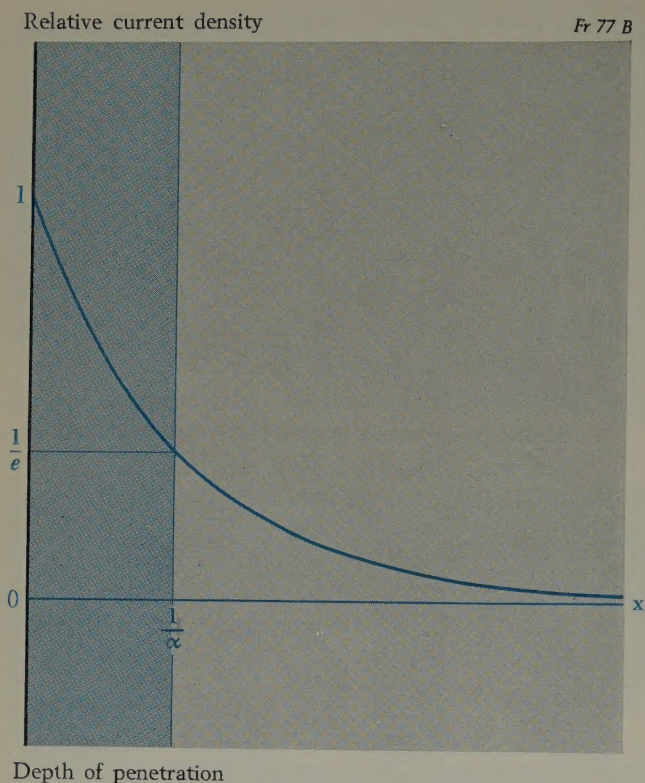


Fig. 3. The current density as a function of the distance x from the surface.

where

J = current density, A/cm²

J_0 = current density at surface, A/cm²

f = frequency, c/s

ρ = resistivity of the work-piece, $\Omega\text{mm}^2/\text{m}$ ($=0.0272$ for pure aluminium at 20°C)

μ_r = relative permeability of the work-piece, ($=1$ for non-magnetic objects)

x = distance from the surface, cm

Thus, the current density falls off exponentially with the distance from the surface, see Fig. 3. For $x=1/\alpha$, the equation gives

$$J = J_0/e = 0.368 J_0$$

At that depth, the current density has dropped 36.8 per cent. It can easily be shown that the main part both of the current (63.2 %) and of the power (86.5 %) is contained in the surface layer with the thickness $1/\alpha$. Therefore, $1/\alpha$ is known as the depth of penetration.

For pure aluminium, at normal mains frequency (50 c/s) the depth of penetration will be

at 20°C ($\rho=0.0272 \Omega\text{mm}^2/\text{m}$) $1/\alpha=1.18 \text{ cm}$

at 500°C ($\rho=0.0816 \Omega\text{mm}^2/\text{m}$) $1/\alpha=2.04 \text{ cm}$

Aluminium alloy has greater resistivity and thus has a greater depth of penetration than pure aluminium at a

given temperature. An alloy with a resistivity twice great as that of pure aluminium will have a depth of penetration which is $\sqrt{2}$ times as great.

It will readily be seen from Fig. 3 that there is a lower limit to the thickness of the billets which can be heated. If a slab with a thickness b is imagined with the current going forward along the one side of the slab with a depth of penetration of $1/\alpha$ and, further, as is usual in the case, with the current going back along the other side of the slab with the same depth of penetration, then it will be seen that the two zones of penetration along the sides of the slab must not encroach upon each other. If they did so, the currents would cancel each other out so that no heat would be developed. It is therefore vital that the depth of penetration $1/\alpha$ should be less than half the width of the slab $b/2$, that is to say $\alpha b > 2$. In spite of this, there will be a certain amount of heating, even though this condition is not fulfilled, but at the price of reduced efficiency. The practical lower limit can be said to be $\alpha b = 1.5$.

For cylindrical work-pieces, the argument is, in principle, the same. By derivation, $\alpha d > 2\sqrt{2}$, where d = the diameter in cm. This means that the efficiency is approximately the same as for slabs for which $\alpha b = 1.5$.

It will thus be found that the minimum dimensions which can be heated at mains frequency (50 c/s) efficiently is:

Aluminium: Slabs with a thickness of 3.1 cm (1.2 in.) and cylindrical work-pieces with a diameter of 5.7 cm (2.2 in.).

Aluminium alloy with a resistivity twice as great as that of pure aluminium: Slabs with a thickness of 4.3 cm (1.7 in.) and cylindrical work-pieces with a diameter of 8 cm (3.2 in.).

TEMPERATURE CONDITIONS

It has been mentioned above that the main part of the power is developed within a surface layer having the thickness $1/\alpha$. The heat is transmitted by conduction from the surface layer in towards the centre. All the time heating is going on and heat is being conducted from the surface layer in towards the centre, the surface layer has the higher temperature. The difference in temperature will be the greater the more rapidly the billet is heated and the greater its dimensions. If it is assumed that the power is developed within a surface layer having negligible thickness, provided that the time of heating is long in relation to the time constant T mentioned below, then the following formulae for the difference in temperature apply¹

¹ According to an investigation carried out at Asea by Dr Ludwig Dreyfuss.

slabs

For cylindrical billets

$$\vartheta_0 = \frac{p b}{4 \lambda}$$

$$\vartheta - \vartheta_0 = \frac{p d}{4 \lambda}$$

$$\vartheta_m = \frac{p b}{6 \lambda}$$

$$\vartheta - \vartheta_m = \frac{p d}{8 \lambda}$$

ere

=the temperature at the surface of the billet, °C

=the temperature at the centre of the billet, °C

=mean temperature, °C

=specific surface power, W/cm²

=thickness of billet, cm

=diameter of billet, cm

=heat conductivity, W/cm degree (=2.18 for pure aluminium at 18°C)

ese differences in temperature are equalised in accordance with the formulae

$$(\vartheta_0)_t = (\vartheta_0)_{t=0} \cdot e^{t/T}$$

$$(\vartheta_m)_t = (\vartheta_m)_{t=0} \cdot e^{t/T}$$

ere

=time, s

=time constant, s (for slabs, $T = \frac{b^2}{\pi^2} \cdot \frac{c}{4 \lambda}$ andfor cylindrical billets, $T = \frac{d^2}{3.832^2} \cdot \frac{c}{4 \lambda}$)

specific heat, Ws/cm³ degree (=2.40 for pure aluminium at 20 - 100°C)

the case of billets having smaller dimensions, for which the depth of penetration is not negligible, the differences in temperature are in fact less than those calculated in accordance with the above formulae.

differences in temperature along the length of the billet arise, for example, if a billet is placed in an unsuitable position in relation to the furnace coil. If the temperature at the one end of the billet is higher than at the other end, the temperature is equalised by the time constant

$$T = \left(\frac{l}{\pi} \right)^2 \cdot \frac{c}{\lambda}$$

ere

=the length of the billet, cm

THE DESIGN OF THE INDUCTION HEATER

The induction coil is made of pure copper in the shape of a tube through which cooling water flows with the object of removing the heat losses. The thickness of the tube on the side which faces the heating chamber should be as great as the depth of penetration of the current in copper at 50 c/s, that is to say, about 10 mm. If the thickness is less, the heat losses will be greater.

It is appropriate to provide the coil with laminated iron cores which have the fourfold object of:

1. Improving the efficiency of the heater.
2. Assuring the greatest possible evenness of temperature distribution along the length of the billet.
3. Preventing the magnetic flux from taking unsuitable routes and causing injurious heating of the structural parts, etc.
4. Assisting in the bracing of the coil, which is particularly important in the case of induction heaters for 50 c/s, because of the large currents which are used for these.

The coils can be designed with room for a single billet or for a number of billets which are pushed through the heater in a series of steps. In the former case, the coil must be provided with terminals so that it can be suited to the length of billet in question, which generally varies within wide limits. This is necessary partly in order to prevent the variations in temperature in the longitudinal direction from becoming too great, and partly to ensure acceptable efficiency. Because of this, it is also generally necessary that a heater with room for a single billet only should be of single-phase design.

A great advantage of the single-phase, single-billet heater is that an even distribution of temperature can be obtained along the length of the billet. If desired, it is also possible to arrange for a gradually falling temperature from the one end of the billet towards the other end. This may be desirable from the point of view of extruding. Another advantage of this heater is that starting is rapid and simple.

A disadvantage of the single-billet heater is that production per unit is limited, since the time of heating must not be too short in order to avoid excessive temperature variations as between the surface and the centre of the billets. Further, its efficiency is lower than that of a multi-billet heater, since the two ends of the coil must project beyond the ends of the billet. Finally, the feeding devices are relatively more expensive.

The greatest advantage of the multi-billet heater is that it can be of three-phase design. Further, it can be made for a high rate of production, and the length of billet can be allowed to vary without the coil length having to be changed.

A disadvantage of the three-phase, multi-billet heater is that it is not possible to avoid uneven temperatures in the billets along their length because of the variations in the magnetic field at the phase intervals. Further, there are certain difficulties when operating with varying speeds of feed, since periodical variations can easily occur in its rhythm (this phenomenon is described be-

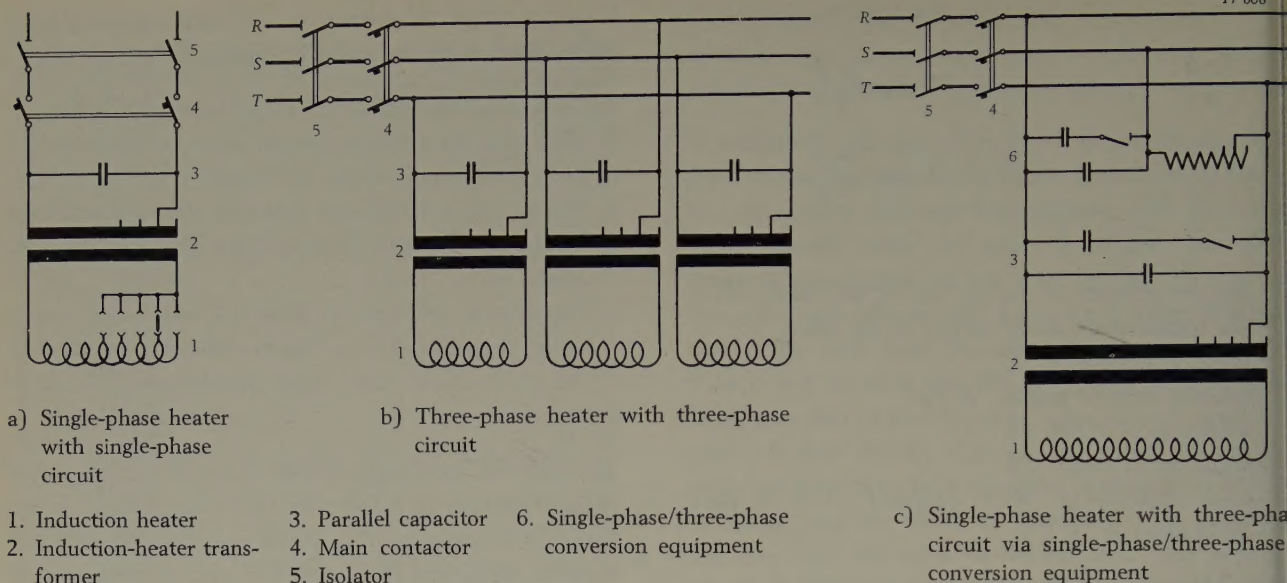


Fig. 4. Various circuit diagrams for induction-heating installations for light-alloy billets.

low under the heading "Operation"). In addition, starting is less convenient than in the case of the single-billet heater.

THE DESIGN OF THE ELECTRICAL INSTALLATION

The induction heater consumes, in addition to the active power, a reactive power which is normally 3 to 3.3 times as great as the active power. Generally, the power supplier prescribes a limitation of the reactive power consumption in relation to the active power consumption. The reactive power of the heater must therefore be compensated by means of a parallel capacitor. This compensation also reduces the amount of current taken from the feeding network so that cables, connection apparatus, etc., can be made on a smaller scale than would have been the case without compensation.

Usually, the heater has to be connected to the power-supply network via a transformer, partly because, for practical reasons, the heater is generally designed for a lower voltage than that of the supply network, and partly because it is desirable to have the possibility of varying the induction-heater voltage, and with it, the circuit.

The elementary diagrams of these installations normally have an appearance as shown in Fig. 4a, b or c. For technical reasons, a transformer with regulation on the high-voltage side should preferably not be designed for a greater variation in the low voltage than ± 20 per cent. If a greater degree of variation is required, such as is the case, for example, with a heater in accordance with Fig. 4a with many coil tapings, a transformer for coarse

regulation must be placed before the transformer for the induction heater.

In the case of a three-phase heater as shown in Fig. 4b the smallest temperature irregularities at the phase intervals, and maximum efficiency, are obtained if the coils are so connected that the difference between the fluxes is 60° . The figure shows a circuit of this kind. Special connections and other devices can be used to reduce the irregularity in temperature still further.

In certain cases, it is advantageous if the voltage of the three coils can be regulated individually. This is explained in greater detail below.

Fig. 4c shows how it is possible, with the aid of single-phase/three-phase conversion equipment to connect a single-phase heater to a three-phase system [see *ASA Journal* 30(1957):1-2, p. 9]. If the load is fully compensated, the three-phase network will be symmetrical and loaded if

$$Q_L = Q_C = \frac{P}{\sqrt{3}}$$

where

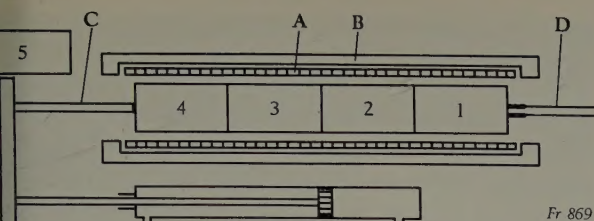
Q_L = the reactive power of the reactor of the conversion equipment

Q_C = the reactive power of the capacitor of the conversion equipment

P = the active power of the load

When using conversion equipment, the reactance of the load should be fully compensated. If the load is incompletely compensated, the conversion equipment tends to make the load on the three-phase network even more uncompensated.

The reactive power consumption of the heater varies for the varying ratios of the transformer, and for the various sizes of the heated billets. Thus, the reactive



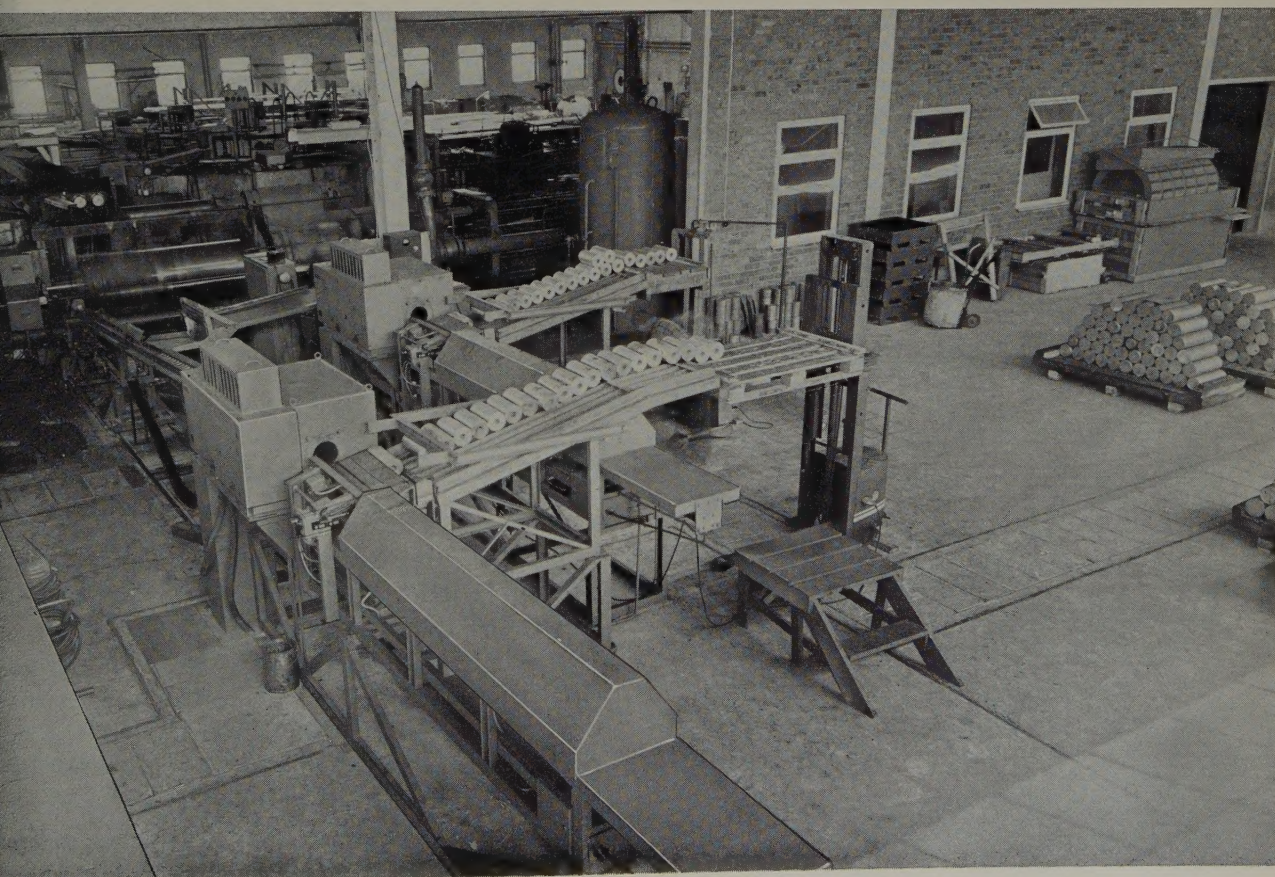
5. Billets A. Coil C. Pusher
B. Laminated core D. Thermo-couple

Fig. 5. The principle of the arrangement of a multi-billet heater (feeding at the left).

power of the parallel capacitor may have to be varied. This is marked in Fig. 4c as a capacitor group which can either be connected in or disconnected. Further, when the load is changed, it is also necessary to vary the capacitor and reactor of the conversion equipment in order to obtain correct symmetry.

A common feature of all such heating installations is that they contain a contactor, with the aid of which the power is switched on and off. The most usual arrangement is for the contactor to be operated automatically

Fig. 6. Over-all view of the induction-heater installation for the heating of light-alloy billets supplied to AB W. Dan Bergman at Södertälje, near Stockholm. (53379. Photo AB W. Dan Bergman)



in conjunction with the insertion and removal of the billets. Further, the contactor is usually automatically operated by means of the temperature regulator of the furnace, as will be described below.

When current flows through the heater coil, considerable mechanical forces arise in the ingots which are being heated. Therefore, they must be held in position during heating. When billets are fed in and out, the power must be switched off.

TEMPERATURE REGULATION

The presses or rolling mills which the heater serves seldom work in a definite rhythm. Therefore, it is not usually possible to arrange the heater for feeding billets at definite intervals of time, which would be the simplest method. It is more advantageous to design the heater so that a billet at the correct temperature can be taken out at the moment when it is needed.

This method of operation requires automatic temperature regulation. For this purpose, a thermo-couple with two separate pointed conductors of chromel and alumel which are pressed against the end of the foremost billet are used. During heating, a voltage arises in the thermo-couple which actuates the temperature regulator. This regulator operates the main contactor which is automatically switched off when the set temperature is

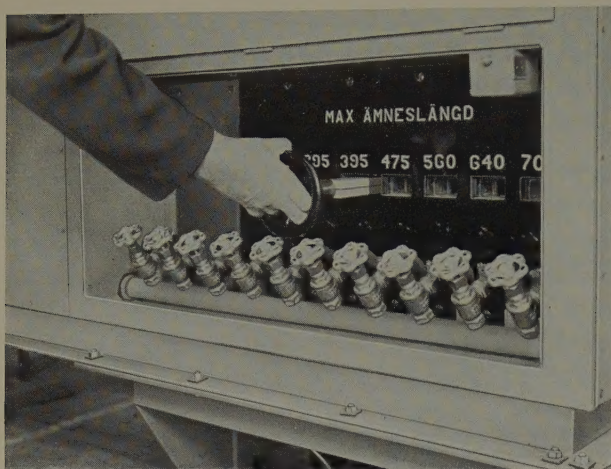
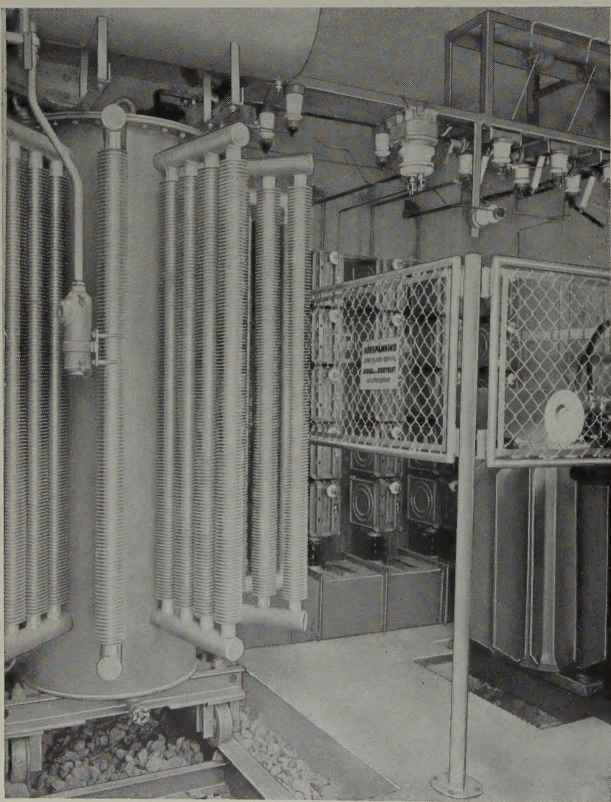


Fig. 7. Connection plug for adapting the length of the coil to the various lengths of billet. (51469)

reached. After tripping, the temperature of the billet falls fairly slowly. When a lower limit is reached, the temperature regulator gives an impulse, thus causing the main contactor to close. The temperature then rises again to the set value, whereupon the procedure is repeated until the billet is taken out. Naturally, the main contactor has to function less often if a broad range of

Fig. 8. The induction-heater transformer, the transformer for coarse regulation and the parallel capacitor are housed in a special transformer room. (53377. Photo AB W. Dan Bergman)



temperature regulation can be accepted than if a narrow one is required.

In order to ensure that the main contactor operates as seldom as possible, the thermo-couple should sense the temperature at a spot on the billet where the temperature during heating is as close as possible to the mean temperature which obtains throughout the entire cross-section of the billet after the power has been switched off. In an actual case, with suitable locating of the thermo-couple, the main contactor was switched off approximately once per minute when maintaining the heat in a solid billet with the diameter of 15 cm, where the temperature alternated between 500° and 505°C.

OPERATION

In both the single-billet, and the multi-billet, heaters the circuit should be set as low as possible, so that the foremost billet reaches full temperature immediately before it would normally be required. By this means, unnecessary large power peaks on the network are avoided, and there is less wear on the main contactor since the periods of heat retaining are short.

In the case of the multi-billet heaters, the problem arises that the furnace tends to take on an uneven rhythm which is difficult to stop. This can be explained in the following way.

Let us assume that there is a heater with four billets fed into it as shown in Fig. 5 and with the power equally distributed over the length of the heater. If the billets are fed forward at a certain rhythm, the temperature in them in turn, reckoned from the input side, immediately before the feeding moment will be $\vartheta/4$, $\vartheta/2$, $3\vartheta/4$ and ϑ (where ϑ = the total temperature rise in the furnace).

If the discharging of the billets stops, for example because of a fault in the press, and the heater has to run for a long time merely retaining the heat, the temperature on all the four billets in the furnace will approach that of the foremost billet. This latter, which because of its high temperature has the highest heat losses, determines the magnitude of the energy which is to be fed into all the billets during the heat-retaining period.

If discharging then continues, only small quantities of energy will be required for those billets which were in the heater throughout the period of heat retaining. The consequence is that the new billets which are fed into the heater do not have sufficient energy fed into them and cannot reach the temperature they ought to have in the various positions. When billet No. 5 becomes the foremost one in the heater, a higher quantity of energy than normal is required for that particular billet to reach its correct final temperature. This in its turn means that billets Nos. 6, 7 and 8 take on a higher temperature than

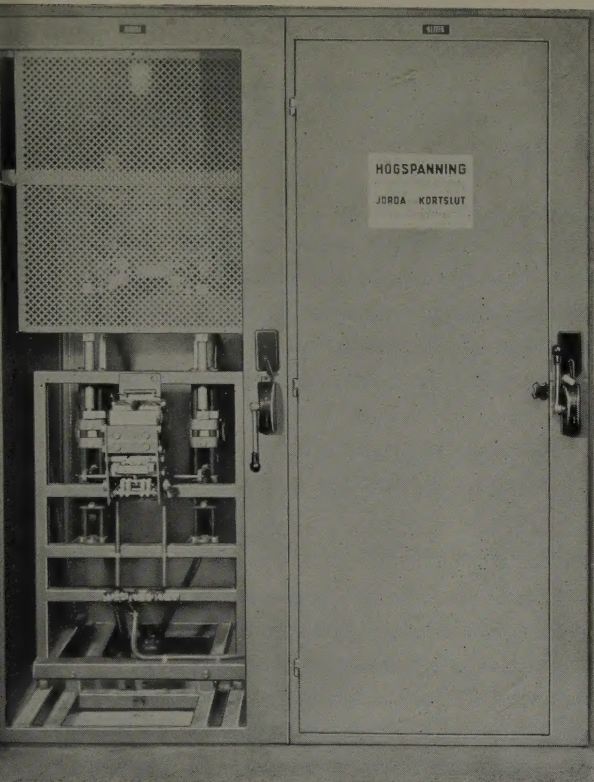


Fig. 9. Each main contactor is built into its own switchgear vehicle for 6,300 V. (53378. Photo AB W. Dan Bergman)

they normally ought to have in their positions, etc. Thus, it will be necessary to wait longer than normal for billets Nos. 5, 9, 13 etc.

One way of damping these fluctuations in the rhythm is to provide the heater with gradually increasing power from the feed end towards the discharge end. This can easily be arranged in the case of a three-phase heater as shown in Fig. 4b, if the three transformers are individually regulable. It should however be remembered that, in particular, long ingots will in that case be hotter at the forward end than at the rear end, and, in addition, the load on the three-phase network will be unsymmetrical (at least if the individual coils are all of the same length). Another way of avoiding these oscillations is to divide up the heater along its length into independent regulating zones. In this case, too, the load on the three-phase network will, at least part of the time, be unsymmetrical.

The most suitable way of starting a multi-billet heater is to fill it first with billets and then to switch on the power and start feeding into the heater, at the normal speed. All the billets fed into the heater at the beginning, except the last one, will then be insufficiently heated and must be put aside after they are discharged. After this, the heater works normally.

It would not be good to start the heater by filling it with one billet at a time at a constant interval of time. The

first billets would then be insufficiently heated, since the impedance of the coil is greater when the heater is not full than when there are billets along the entire length of the heater, and thus the current is less if the voltage is constant. The heater would thus be subjected to the uneven rhythm which has been described above.

INDUCTION-HEATING INSTALLATION FOR 2×300 kW, 50 c/s

Asea have recently supplied to AB W. Dan Bergman at Södertälje, south of Stockholm, an installation for heating light-alloy billets with the following dimensions:

Diameter 150 mm (59 in.), length 235 – 700 mm (92 – 275 in.)

Diameter 125 mm (49 in.), length 235 – 475 mm (92 – 185 in.)

The heating temperature can be set over the range 450 – 530°C and production is 50 billets per hour.

Heaters

The installation consists of two single-phase heaters, each intended for the heating of one billet at a time. The appearance of the heaters can be seen from Fig. 6. The billets are placed in a sloping magazine and are fed into the heater with the aid of a compressed-air-operated pusher. Mounted in this is a thermo-couple of chromel and alumel. Thus, the temperature is measured at the rear end of the billet.

At the forward end of the heater, there is a stop which can be moved in and out, which determines the position of the billet in the heater during heating. The stop can be set so that the position of the billet can be adjusted in relation to the inductor coil. This latter is wound more tightly at the forward end than at the rear end, so that the billet is given a temperature which is about 30°C higher at the forward end than at the rear end. The length of the inductor coil can easily and rapidly be adjusted for various lengths of billet with the aid of a connection plug, see Fig. 7.

The inductor coil is water-cooled. It is divided up into a number of cooling circuits for which the quantity of water can be set individually by means of a tap. In addition, each circuit is provided with a thermometer and a flow indicator.

The electrical installation

The elementary diagram for the heater is similar to the one shown in Fig. 4a. The heaters are connected to the three-phase network in a V-connection. Each transformer is oil-insulated, self-cooled and designed for 1,100 – 730 kVA; the secondary voltage is regulable in

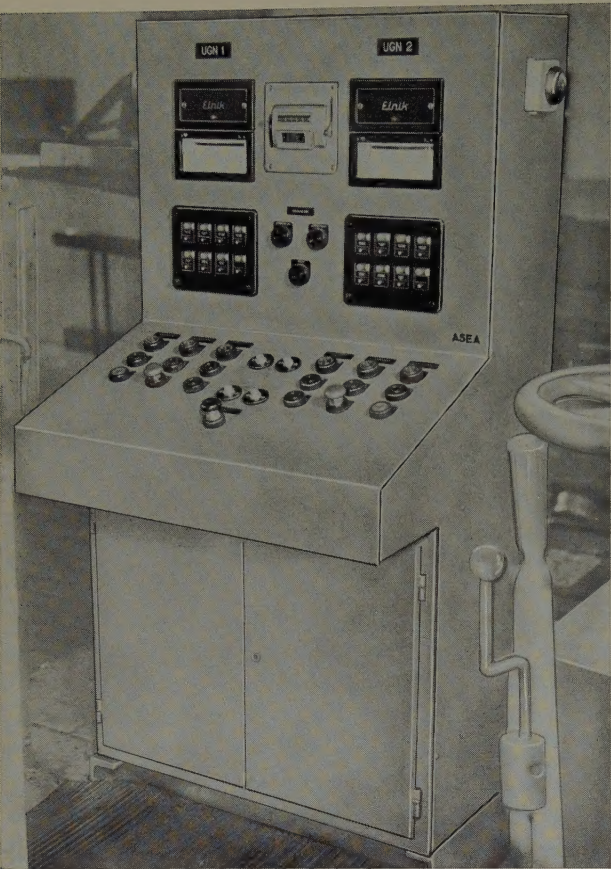


Fig. 10. The control desk is common to the two heaters and contains, amongst other things, pushbuttons for switching the power on and off and for feeding and discharging the billets. (53380. Photo AB W. Dan Bergman)

several steps. Before the transformer there is an oil-insulated, auto-connected transformer for coarse regulation. By this means, the secondary voltage is regulable within a large range and it is possible to vary the input to the heater in small steps down to low values.

Between the induction-heater transformer and the transformer for coarse regulation there is a parallel capacitor which consists of self-cooled units of Asea type CTD 2. The above-mentioned parts of the installation and the necessary instrument-transformers are built into a separate transformer room, see Fig. 8. The induction-heater current is transmitted from the furnace transformer to the heater by means of copper bars. The two main con-

tactors of the installation (of Asea type EHLA) are air-type contactors provided with d.c. magnets for the operation, so that long life may be expected. Each contactor is mounted in a switchgear cubicle for 6,300 V, see Fig. 9.

Further, each of the two parts of the installation contains its own control cabinet with the necessary instruments and protective relays, and there is a common control desk. The appearance of the latter can be seen from Fig. 10. It contains pushbuttons for the switching on and off of the power and for the feeding in and discharging of the billets. Further, there are temperature regulators for the two heaters and signal stations for the indication of any possible faults in the installation.

Experience in service

The installation described above has proved to be very flexible. It can easily be reset for various billet dimensions, heating temperatures and power values. The press operator can fetch a hot billet as soon as the press is ready for a new operation. If the press breaks down the billet remains in the furnace and is kept hot at the set temperature with very satisfactory accuracy ($\pm 5^{\circ}\text{C}$). There are no problems connected with starting up or with rhythmic oscillations of the type previously described here.

The specific consumption of energy for heating from 20°C to 500°C has been measured for several dimensions of billet, and the following values were then obtained:

Dimension mm			Specific consumption of energy kWh/tons	
External diameter	Internal diameter	Length	Aluminium	Aluminium alloy
150	0	700	315 à 320	300 à 305
150	0	395		335 à 340
150	86	396		335
125	0	550		360
125	0	392		370
125	0	260	445	

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2. Hammarlund, P. E., Sundberg, Y., Induction heating for forging. Asea Journal 30(1957):10, pp. 127-134.

ELECTRONIC AIDS FOR HIGH-VOLTAGE TESTS

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Asea Reg. 097

Much time and trouble can be saved during high-voltage tests by the increased use of electronic aids. These ensure both greater efficiency and more reliable test results. The article describes a number of typical aids of this kind which were developed at the High-voltage laboratory at Ludvika.

High-voltage tests require expensive equipment and considerable space. It is therefore essential that the premises where testing is to be carried out should be utilised as effectively as possible in order to keep the cost per test down. Operations which cause fatigue and waste time should, if possible, be avoided. Settings and readings should be as few and as simple as possible in order to facilitate checking and to prevent errors. The time required for maintenance should be reduced to a minimum by ensuring a high degree of operational reliability and easy replacement of defective parts. Naturally, at the same time, the demands on the accuracy of measurement should be completely satisfied.

As far as the measuring equipment is concerned, these requirements can be fulfilled by the increased use of electronic measuring instruments. Thus, during alternating voltage tests, the sphere gap can, with advantage, be replaced by a *peak voltmeter*. The voltage divider required could suitably be a capacitive one, and could possibly be formed by means of a tapping on the capacitor bushing of the high-voltage transformer. It is possible to locate the instrument very conveniently for reading and measurement-range selection by, for example, mounting it flush in a test-control desk.

The curve shape of the voltage can easily be checked by means of a *curve-shape indicator*. This is a small oscilloscope provided with automatic amplitude control so that the height of the picture is constant, irrespective

of the amplitude of the measuring voltage. It can suitably be connected up in parallel with the peak voltmeter to the same capacitive voltage divider.

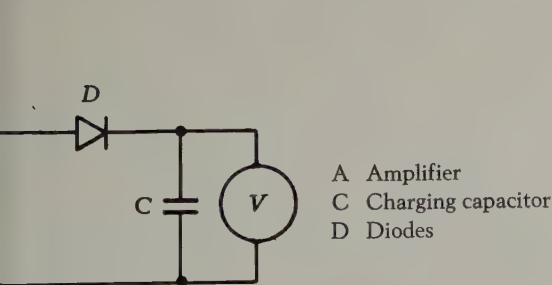
The most important instrument required during impulse tests is the *cathode-ray oscillograph*, which is normally used both for the indication of faults and for checking the impulse shape. Consequently, considerable demands are made both on the accuracy of measurement and freedom from interference as well as on ease of operation and reliability in service.

The setting up of the test circuit by taking oscillograms of the test impulses, and then interpreting the oscillograms, is a lengthy procedure. There are two better methods of doing this, each of which supplements the other to some extent. In the one method, the impulse generator and the impulse-forming elements are disconnected and replaced by an *impulse setting device* which gives off *repeated impulses*, the shape of which can be set, at a low voltage. The impulses are adjusted to the desired shape with the aid of a calibrated oscillograph, whereupon the set values are read off and corresponding impedances connected to the main impulse circuit. This device has also proved to be valuable in those transformer tests in which the impulse impedance has to be increased by leaving the low-voltage winding open or closing it via a resistor. In these cases, it is then a simple matter to check that the impulse stresses are not too great for this winding.

The other method is to measure the characteristic times of the impulses by means of an *electronic time-measuring device with direct indication*. In the simpler cases, this probably provides the most rapid means of setting.

It should be pointed out that, in order to achieve a correct measuring result, all the above instruments are dependent on the complete adequacy of the voltage di-

Fig. 1. Peak voltmeter for alternating voltage. (Fr 711)



a) Basic circuit

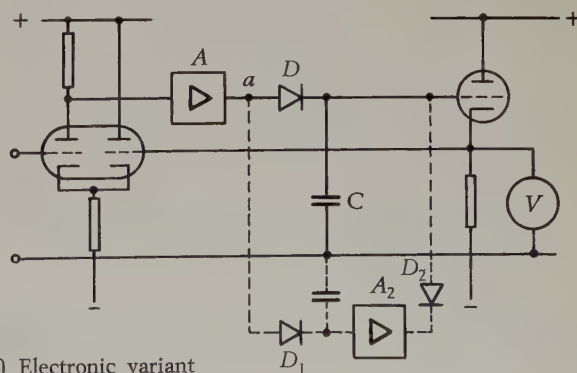




Fig. 2. Peak voltmeter for alternating voltage in the form of a unit of plug-in type for mounting on a panel (the power supply unit not shown). (52287)

viders or shunts. In the case of impulse tests in particular, it is also necessary to pay due attention to the design of the measuring circuit in its entirety. These questions have been dealt with in a previous article by Hyltén-Cavallius [1].

PEAK VOLTMETER FOR ALTERNATING VOLTAGE

The conventional basic type of peak voltmeter (Fig. 1a) has certain disadvantages which make it unsuitable for use as a high-voltage voltmeter. In the first place, it takes direct current from the measuring point and thus cannot be used with a capacitive voltage divider. The resistance at the measuring point must be low, which also excludes the use of a voltage divider with high resistance. The return time, i.e. the response when the voltage is falling, is very long and cannot be speeded up without sacrificing the accuracy of measurement.

Certain circuit variations will eliminate the d.c. component and reduce the return time [2]. In comparison with these, the electronic variant presented here is rather more complicated and requires a power supply from the mains, but is, on the other hand, more accurate and has a considerably more rapid return [3]. It also permits the use of a precision instrument with low resistance and extra control instruments or recording devices.

The principle can be seen from Fig. 1b. The actual measuring circuit is marked in solid lines and the return

circuit in broken lines. Disregarding the latter, operation is as follows: In the input stage, the instantaneous value of the measuring voltage is compared with the direct voltage via the voltmeter V . Every tendency of the former to become greater than the direct voltage results in an output voltage which, after amplification, causes a charging current to flow to the capacitor C across the diode D . This causes the capacitor voltage to increase and with it the voltage across the voltmeter until a state of balance is achieved in the input stage. Thus, the voltage of the voltmeter will take on the positive peak value of the measuring voltage.

The object of the return circuit is to discharge the capacitor C when the peak value of the measuring voltage is lower than the voltmeter voltage. A sign of this is that the voltage in the point a stops pulsating. A peak rectifier with a relatively short time constant connected to this point normally provides an output voltage which blocks the amplifier A_2 and prevents the discharge of C across the diode D_2 . When the pulsations in a cease, the blocking voltage drops rapidly and C begins to be discharged. Discharging ceases when the voltage has gone down to the instantaneous value of the measuring voltage, when a pulsation is obtained in a and the return circuit is again blocked.

Fig. 2 shows an instrument without its mains supply unit. It is reconnectable for a positive or negative peak value and for a mean value. The measuring error is less than 0.5 per cent (excluding the external voltage divider) for the frequency range 35 c/s to 3 kc/s. The response time both in the case of increasing and falling measuring values is the same as for the indicating instrument alone (about 1 second). The input impedance at 50 c/s is about 10 M Ω .

CURVE-SHAPE INDICATOR

As a rule, the peak value of the alternating voltage is regarded as being the decisive factor determining the test result. However, very little is known of the effect of the curve shape, for which reason, when carrying out accurate tests, an attempt is made to arrive at small deviations from the sinusoidal shape.

To check the curve shape it is suitable to use an oscillograph such as the curve-shape indicator described here. On this, a recurrent pattern is obtained comprising one cycle of the test voltage. Stabilisation of the high voltage and the cathode current means that the focus and intensity only have to be adjusted on rare occasions. In order to keep the picture height constant irrespective of variation in the measuring voltage, use is made of a vertical amplifier with automatic amplitude control in the input stage. The height of the picture varies at most by 20 per cent

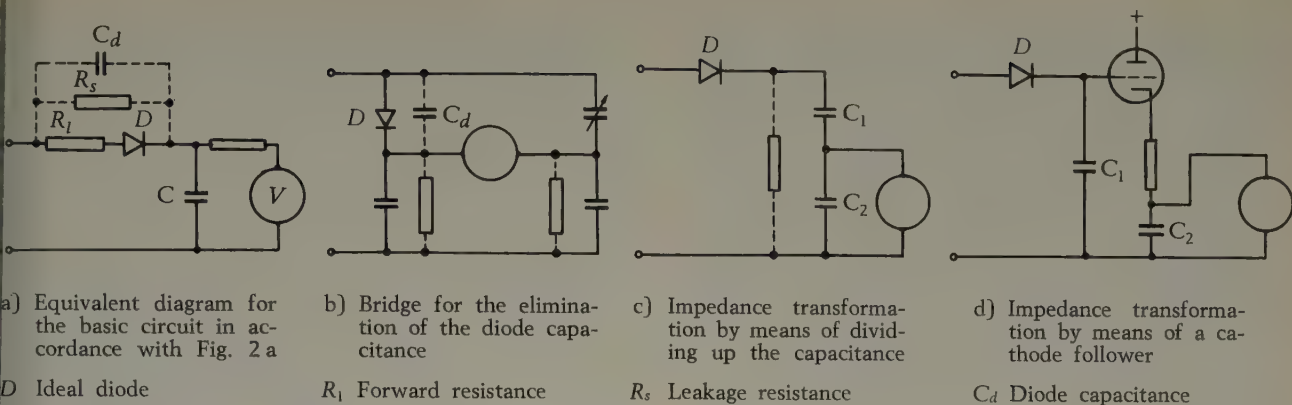


Fig. 3. Peak voltmeter for impulse voltage. (Fr 712)

when the input voltage is changed in the ratio 1:50. Distortion in the indicator itself is, in this case, less than 1 per cent.

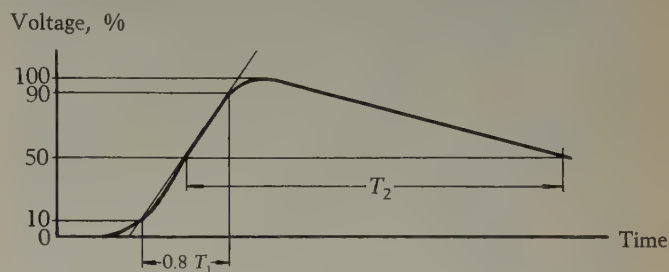
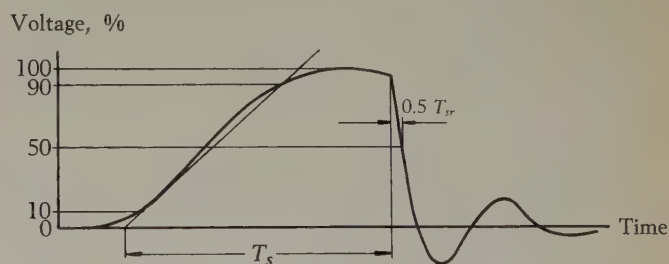
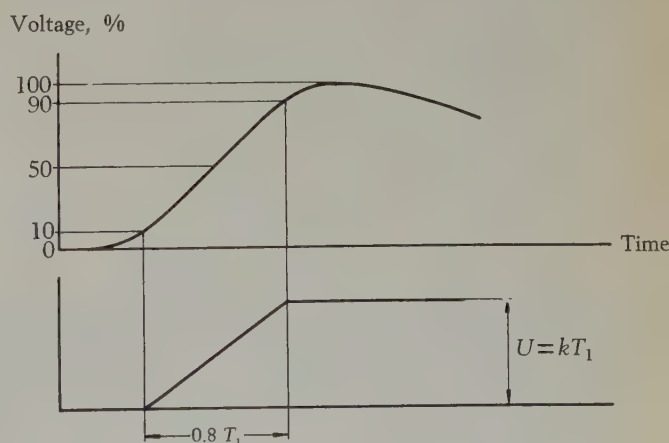
The indicator has been designed as a supplement to the previously described peak voltmeter and is intended to be connected in parallel with this. It has no control devices, but the focus and intensity can, if necessary, be adjusted with the aid of a screwdriver.

PEAK VOLTMETER FOR IMPULSES

There are two main problems when measuring the peak value of individual impulses. Firstly, the measuring device must be sufficiently rapid in action so that it has time to react for the peak value before the amplitude of the impulse begins to fall off, and secondly, the value obtained must be held for a period which is very long when compared with the response time. The Swedish Standards for voltage tests, SEN 26-1950, prescribe for the measuring of a full wave a charging time of less than 1 μ s, but, in many cases, a considerably shorter time than this is desirable.

Fig. 3a shows the basic diode circuit with reference taken to the deviations from the ideal diode properties. It is clear that the forward resistance of the diode along with the resistance in the measuring point determine the maximum permitted charging capacitance. Practical values of 10-100 pF are obtained here. The diode capacitance which amounts to a few pF is, in comparison with this, not negligible, but gives rise to a fault voltage during the blocking interval. Further, if the charge is only to be reduced by about 1 per cent or so in about two seconds, a leakage resistance of the order of size of $10^{12} \Omega$, would be required, and this can hardly be arranged.

The effect of the diode capacitance can be eliminated by means of a bridge connection as shown in Fig. 3b. By dividing up the charging capacitance in accordance with Fig. 3c, an "impedance transformation" is obtained, the result of which is that the leakage resistance required

a) Nominal duration of the front T_1 and time to half-value T_2 in accordance with Swedish Standard SEN 26-1950b) Time to chopping, T_s in accordance with Swedish Standard SEN 26-1950

c) Measuring the duration of the front

Fig. 4. Measuring characteristic times for impulses. (Fr 713)

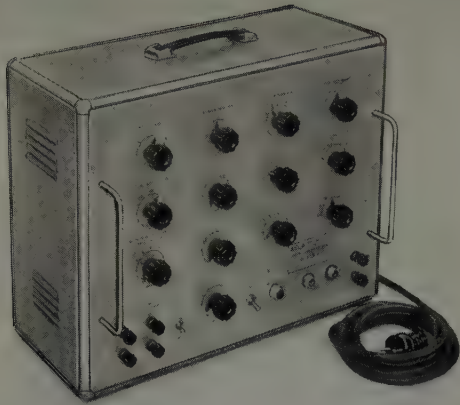


Fig. 5. Impulse-setting device in the form of a low-voltage model of a surge generator and impulse circuit. (52289)

is lower, but then the output voltage is lower too. Finally, if a cathode follower is introduced in accordance with Fig. 3d, the capacitance can be successively raised without any noteworthy voltage loss.

A combination of methods b-d is used in a new peak voltmeter which is now under development. The indicating instrument is driven by an electrometer amplifier, thus ensuring that the reading shown drops by a maximum of 0.1 per cent per second. Peak values with a duration down to $0.3 \mu s$ are accurately measured.

TIME MEASURING DEVICE FOR IMPULSES

The Swedish Standards for voltage tests, SEN 26-1950, define the duration of wave front and time to half-value in the case of a full wave as shown in Fig. 4a. The definitions of the time to voltage collapse and duration of the voltage collapse can be seen from Fig. 4b. The times as defined are suited to be extrapolated from the oscillograms.

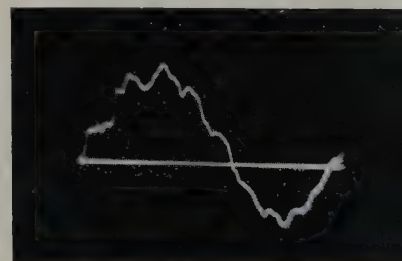
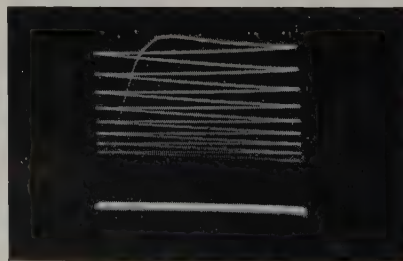
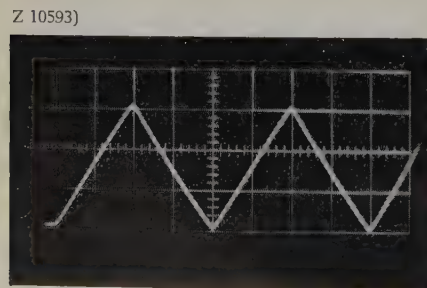
However, it is possible to measure the times directly in accordance with the definitions in the standards, pro-

Fig. 6. Oscillograms showing

a) Sweep voltage with zig-zag time sweep

b) Normal 1/50 impulse with time sweep in accordance with a

c) Impulse current with ordinary linear single-time sweep



vided that the impulse amplitude is first determined by means of a previous impulse. By this means, the necessary reference levels are obtained, in the case of determination of the duration of the front the 10 per cent and 90 per cent levels, and for the time to half-value the 50 per cent level.

The time-measuring device described is intended to be used as an accessory to the peak voltmeter for impulses. The peak value which is measured with the aid of this is retained by means of a servo-set. The required reference-level voltages are obtained from this direct voltage, which is applied to the time-measuring device, with the aid of potentiometers.

At the moment when the amplitude of the incoming pulse passes through a certain level, the measuring sequence is started or interrupted by means of high-speed, flip-flop circuits. Thus, when determining the duration of the front, the sequence is started when the 10 per cent level is passed and interrupted when the 90 per cent level is reached. The measuring sequence consists of a linearly rising voltage, the final value of which is thus proportional to the period of connection, that is to say, to the time which is to be measured (Fig. 4c).

As in the case of the peak voltmeter, an electrometer amplifier is used to retain the measured value for the time required.

Other national standards have reference levels which deviate somewhat from those of the Swedish ones. Only minor adjustments need be made to the apparatus in order to suit it to these.

IMPULSE-SETTING DEVICE

This device is not strictly an electronic apparatus, but it has been included here since, from the points of view of design and operation, it is in the same class as the devices described above.

In principle, the device consists of a low-voltage model of a surge generator and impulse circuit [4]. A relay with mercury-wetted contacts is used as the surge gen-

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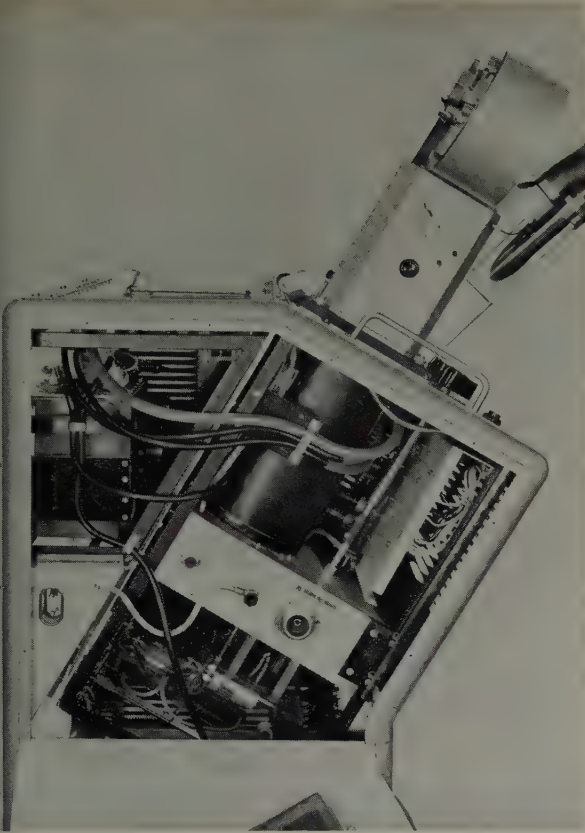
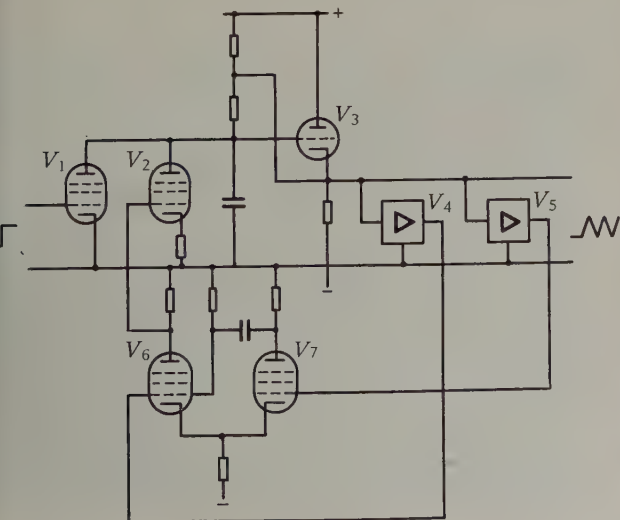


Fig. 7. Impulse-test oscillograph with the side plates removed. The large coaxial terminal is for the measuring input and the small one for tripping. (52286)

erator. The setting parameters are so selected that they correspond directly to conditions in the main circuit. Thus, the capacitances and resistances in the surge generator can, for example, be mimicked in various arrangements of the circuits.

Fig. 8. Simplified diagram for a zig-zag time sweep. Its function is described in the text. (Fr 714)



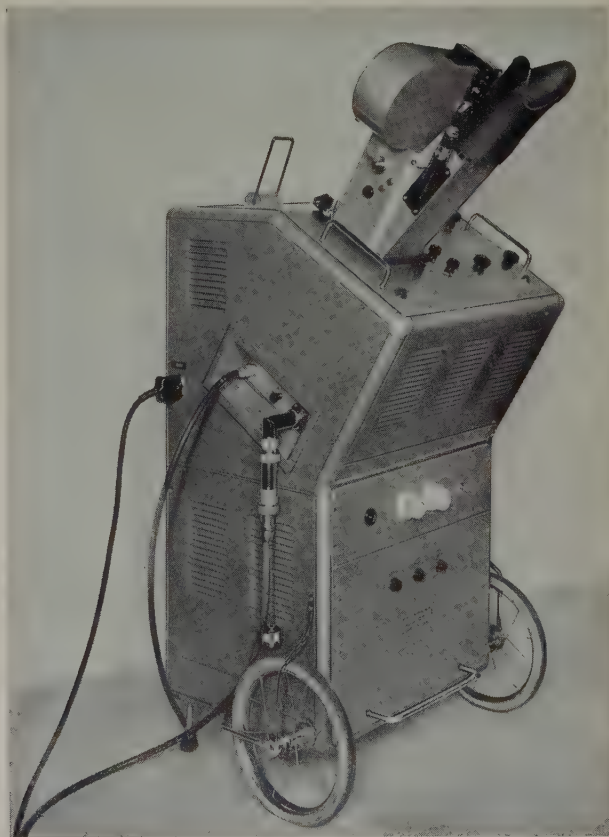
No further description is probably necessary over and above these introductory remarks. The appearance of the apparatus can be seen from Fig. 5.

IMPULSE-TEST OSCILLOGRAPHS

When carrying out impulse tests, especially when testing transformers, both the voltage and the current through the test objects are measured. In both cases, input voltages on the oscillographs of the same order of size are obtained with the aid of external voltage dividers and shunts. Thus, in principle, the same type of oscillograph can be used for both tasks.

However, for voltage indication it is advantageous to use a special time sweep which moves backwards and forwards (zig-zag sweep) in accordance with Fig. 6a, thus greatly increasing the dispersal along the time axis. The method is made possible by the characteristic shape of the impulse voltage, and results in oscillograms similar to that shown in Fig. 6b. On the other hand, it is unsuitable for current indication since a current oscillogram often has a very complicated appearance (Fig. 6c), and use is made here of an ordinary linear single-time sweep. If necessary, use is made instead of several oscillographs connected in parallel and having differing speeds of sweep. This type of oscillograph has been provided with

Fig. 9. Impulse-test oscillograph with camera. (52285)



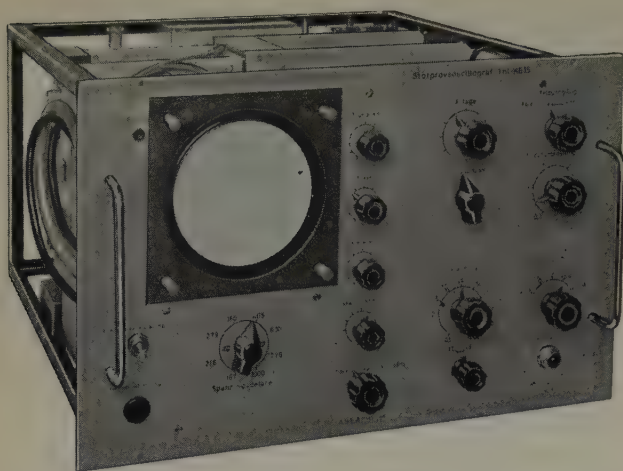


Fig. 10. Impulse test oscillograph. The indicator unit with its operating panel. (52290)

a variable trip delay, which allows of the detailed study of, for example, a chopped tail on an expanded time scale.

Otherwise, the two types of oscillograph are similar. The cathode-ray tube works with a post-acceleration voltage of 20 kV, which allows of reproducible oscillograms at recording speeds of more than 1 m/ μ s. The high voltage is stabilised as are the other direct voltages.

A good impulse-test oscillograph is required to reproduce satisfactorily impulses chopped at the front at times down to a few tenths of a microsecond. The greatest problem here is the disturbance level. In particular, the impulse current gives rise to considerable voltage drops in the earth system, which cause disturbances in the measuring and tripping cables as well as in the low-voltage supply network. Similarly, capacitance currents cause a voltage drop in the internal earthing system of the oscillograph. Steep field changes in the neighbourhood of the oscillograph also make considerable demands on the efficiency of the screening.

Disturbances on the supply network are suppressed by means of isolating transformers with double electrostatic screens, and by means of low-pass filters at the supply-network entry. The cathode-ray tube is surrounded by a mu-metal screen, which is double at the neck of the tube and is provided with an intermediate copper screen. The entire input circuit is enclosed in an aluminium box which surrounds the neck of the tube opposite the terminals of the deflector plates. The measuring and tripping terminals are situated on the one end of the box, which serves as an earthing reference point for the entire oscillograph (Fig. 7).

The measuring input is provided with a voltage divider rated at 1,000 Ω combined with a range selector. (For adaptation to the wave impedance of the measuring cable, use is made of an external parallel resistor which

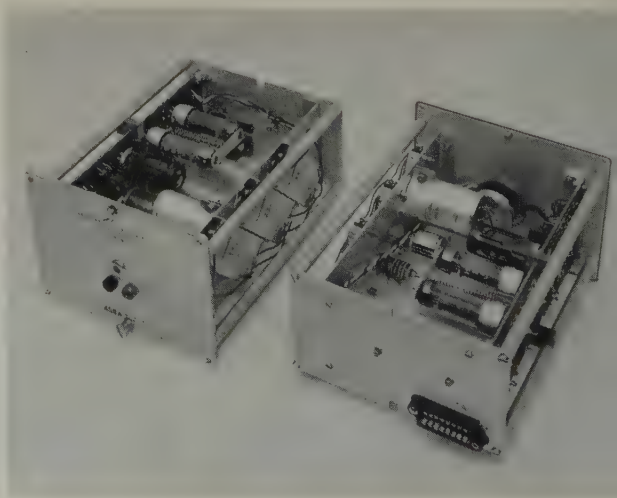
can be screwed on.) The steps of the range selector form a geometric series with the quotient $\sqrt{0.6}$. This quotient has been selected in order to make possible the same oscillogram amplitudes for setting and calibrating impulses at the 60 per cent level as for impulses at full voltage, which facilitates comparison. The maximum input voltage is about 2.5 kV for full deflection, but the voltage divider can withstand twice this amount without the slightest difficulty, and this fact contributes to reliability in service. Very satisfactory stability has been achieved by using wire-wound resistors. Low inductive methods of winding allow of time constants of 0.015 μ s or less.

The tripping circuit has been so designed that the oscillograph is tripped satisfactorily both by positive and negative impulses with amplitudes from 50 to 500 V, without any reconnection or setting being required. The time lag is 0.1 μ s.

As has been mentioned above, for current indication, use is made of a linear single-time sweep. To achieve linearity, use is made of a positive feedback circuit via the cathode follower (bootstrap sweep). A phase inverter provides an output voltage which is symmetrical to earth. The shortest sweep time is 0.5 μ s and the longest 2 ms.

Fig. 8 shows a simplified circuit diagram for the zig-zag sweep (5). This can be regarded as a modified bootstrap sweep where the return is also made linear by arranging the discharge via a pentode. The change-over in the end positions of the sweep is arranged by means of a flip-flop V_6 - V_7 , controlled from two pulse amplifiers V_4 and V_5 . A special blocking tube V_1 releases the sweep for a time corresponding to the set unblanking time. A phase inverter of the same type as is used in the single sweep (not included in the drawing) ensures

Fig. 11. Stabilised direct-voltage devices designed as units of plug-in type. (52629)



that the output voltage is symmetrical and has an amplitude of about 550 V. The time between the turning points of the sweep can be selected by means of a switch and be 1, 2, or 5 μ s.

The oscillographs for the impulse tests have been designed mechanically bearing in mind ease of operation and maintenance (Figs. 9 and 10). The specially designed oscillograph camera [6] contributes to the ease of operation. It has a magazine which takes about 35 m of 35 mm film, shears and changeable cassettes as well as an observation hood which allows of simultaneous observation and exposure.

MAINTENANCE AND RELIABILITY IN SERVICE

Unreliable measuring equipment can cause damage to the object being tested and give faulty results. Therefore, a requirement for the increased use of electronic aids is that they should fulfil all reasonable demands for reliability in service and speed of maintenance.

These demands are fulfilled in the apparatuses described, by means of the use of high-class, carefully selected components with adequate margins as far as power and voltage are concerned. As far as possible, use is made of non-critical circuits, and thorough tests are carried out in the prototype stage (marginal tests). From the design

point of view, the demands made on reliability in service are satisfied by, amongst other things, the use of printed circuits. The life of most components falls off rapidly as temperature increases, for which reason cooling has been arranged with great care.

Repairs and inspections can never be entirely avoided, for which reason the apparatuses have been designed with a view to rapid and easy servicing. One of the measures taken with this in view is the use of plug-in type units (Fig. 11). By the standardisation of such units, well thought-out building elements for use in small series of apparatuses have been obtained, where manufacture using only the basic elements would have been too costly.

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LOOP REGULATION IN ROD AND STRIP MILLS

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Asea Reg. 4950, 5731

The Asea photo-electric angular co-ordinate locator was specially designed with reference to the problems of regulation in rod and strip mills. However, it can also be used as an indicator in many other situations where the position of an object radiating heat is to be determined or regulated. It should therefore have a wide range of application, especially in the iron and steel industry.

For many years now, the requirements of Swedish rod and strip mills have been very strict in respect of the tolerance limits of the rolled material. It was realised at a very early stage that stretching of the material between the roll stands in continuous rolling mills had to be avoided if the tolerance limits were to be maintained along the entire rolled length. As far as electrical driving equipment is concerned, this led, in rod and strip mills, to the supplementing of the speed regulation of the motors by loop regulation.

As early as 1936, SKF took into service, at Hofors Bruk, a rod mill in which the speeds of the final stands were controlled by loops between the stands [Asea Journal 6(1939):2-3, pp. 18-37]. The rods are stretched across

a roller in a compressed-air-operated loop-lifter to which a rheostat is connected. The device can be seen in Fig. 1. The rheostat is incorporated in the control circuit to correct the speed regulation of the roll motor for the following stand. At this time, for rapid regulation, Asea made use of ticking regulators which regulate the excitation of the motors by means of impulse exciters in such a way that a suitable loop is maintained between the stands. The outgoing speed of the rod is almost 20 m (65 ft) per second, and the original regulating equipment is still working completely satisfactorily after more than 20 years of service.

Later, several similar regulating equipments were supplied for continuous rod mills. The same method of regulation has also been applied to continuous strip mills, for example, at Hagfors [Asea Journal 30(1957):4, pp. 51-64], where the six finishing stands are regulated by means of pneumatic loop-lifters, as can be seen from Fig. 2.

In the continuous rod mill at Fagersta [Asea Journal 28(1955):10, pp. 143-156] Asea introduced automatic regulation of horizontal loops in repeaters. In this plant,



Fig. 1. Pneumatically operated loop-lifter in a continuous rod mill built in 1936. Hofors Bruk, Sweden. (54514)

the speed of the last eight roll motors is controlled by an equivalent number of loop regulators. The loop moves a vertical roller, as can be seen from Fig. 3. The roller is mechanically connected to a regulating resistor which introduces a voltage into the closed regulating circuit for the speed regulation of the motor. At Fagersta, the ticking high-speed regulator has been replaced by static transducer regulators which proved to be very reliable and, in addition, do not require any inspection and maintenance. During recent years, many rolling mills have been fitted with automatic loop regulation of the same type as at Fagersta and in all these works the transducer regulator has also been used since it has proved to be the most reliable and suitable regulating amplifier available.

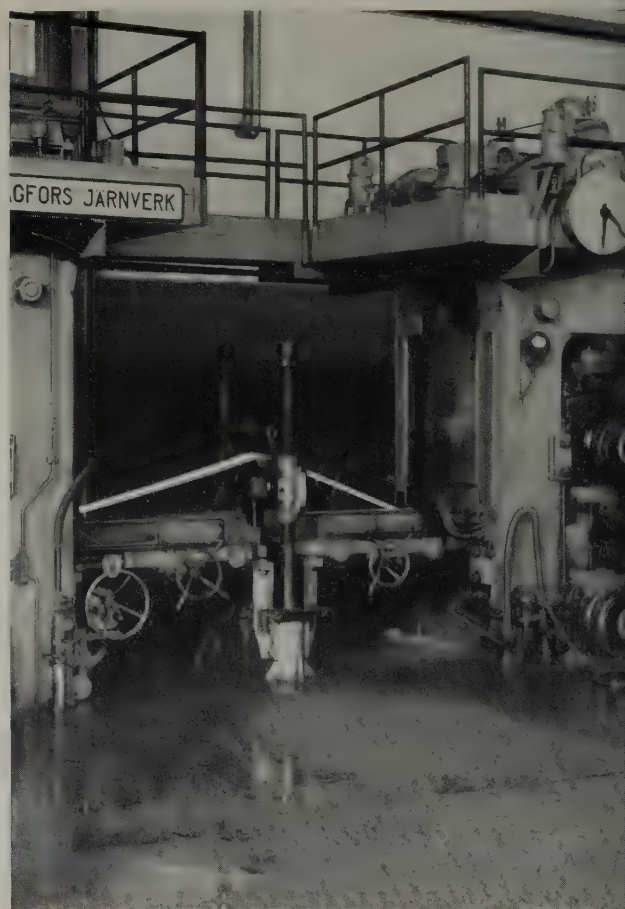
In the earlier installations, the position of the loop has always been transmitted to a potentiometer in the regulating circuit by means of a mechanical device. This method has certain disadvantages. In a mechanical device which has to work intensively it is difficult to avoid a certain amount of play, which, in cases such as these, may cause difficulties in the closed regulating circuit. The contact roller, which lies against the rod or strip, rotates extremely rapidly and the problem of providing adequate bearings is a difficult one. Further, when the roller becomes worn, it may cause undesirable marks in the material. The resistor itself has to be specially made in order to withstand the heavy duty since it has proved that rheostats of standard type have to be replaced far too often.

For this reason, Asea have developed a position transmitter for the loop which works without any mechanical contact with the material and is therefore independent of the design of the rolling mill. The only condition is that the material should be visible and have a tem-

perature of at least about 300°C (570°F). This is because the transmitter is of photo-electric type and in fact, measures the angular co-ordinate of the boundary between a warm object and a cold background, or vice versa. The principle of the device can be seen from Fig. 4.

A rotating mirror or lens is driven by a synchronous motor fed at supply frequency. This mirror reflects the radiation from the hot material on to a photocell sensitive to infra-red rays which thus emits impulses having a phase position dependent on the angle of incidence of the incoming radiation. The impulses are amplified and transmitted as ignition impulses to a thyatron regulator, the anode voltage of which is in phase with the voltage supplied to the above-mentioned synchronous motor. Thus, the output voltage of the thyatron regulator is dependent on the position of the radiating loop and can therefore be used as a signal in the control circuit for the speed regulation of the rolling-mill motors. This voltage can also be fed to a voltmeter, giving a reading proportional to the loop position, enabling remote setting of the loop in a suitable position from a control desk without seeing the rolling mill.

Fig. 2. A loop-lifter in a continuous strip mill. Hagfors Järnverk, Sweden. (47677)



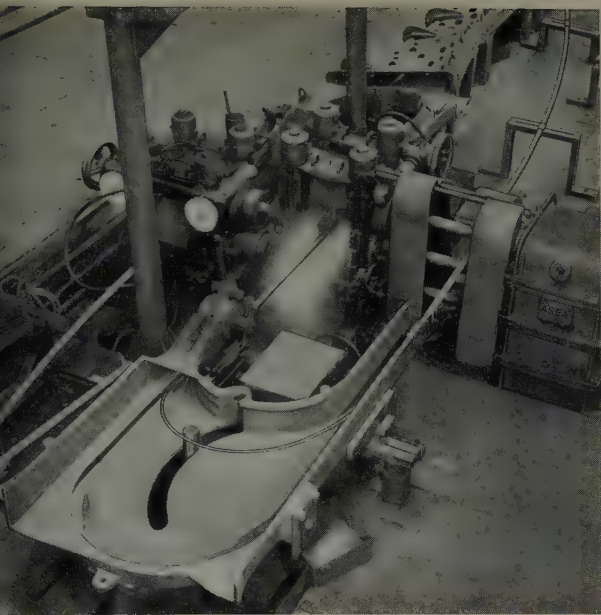


Fig. 3. Horizontal repeater with built-in potentiometer resistor for loop regulation. Fagersta Bruks AB, Sweden. (39086)

In the equipment supplied hitherto, the thyatron amplifier has been designed as a separate unit intended to be placed in the control panel in the machine room. Only the photocell part itself, the rotating mirror and the first amplifier stage are then placed out in the rolling mill. The separate thyatron part can then easily be fitted into various types of control circuits which can be a considerable advantage if older rolling mills are to be fitted with loop regulation. However,

Fig. 4. Elementary diagram of the Asea loop regulator.

- 1. Rotating mirror
- 2. Synchronous motor
- 3. Amplifier

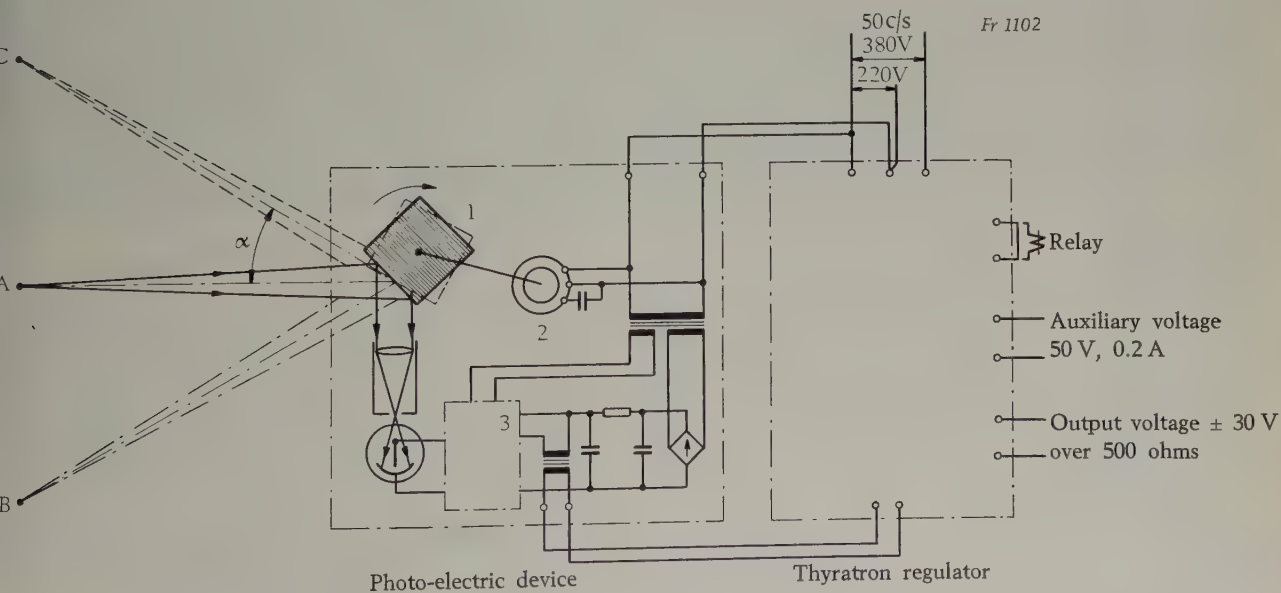




Fig. 5. Continuous rod mill with six stands. The position of the hanging rod loop is indicated by a photo-electric angular co-ordinate locator. Soc. Nazionale Cogne, Aosta, Italy. (54515)

never be stretched between the stands, but the length of the external loops then depends on the grooves in the rolls, temperature etc. On the other hand, if the largest loop is controlled, it is impossible to prevent the smallest loop from becoming so short in certain situations that the rod is stretched. However, a certain improvement is always achieved and supervision is certainly better than if the size of the loop had been regulated by hand.

The Asea loop regulator has been specially designed bearing in mind the regulating problems of rod and strip mills. It is, however, suitable for use as an indicator in many other situations where the position of an object which is radiating heat is to be measured or regulated. Such applications are, for example, the acceleration and retardation of reversible hot rolling mills or the setting of the shearing length in hot shears. In addition, the position of cold objects can be indicated if they are placed against a background which is radiating heat or light and which may consist of, for example, a fluorescent tube or an electrically heated wire. Thus, the Asea photo-electric angular co-ordinate locator is an apparatus with many uses and it should have a wide range of application, especially in the iron and steel industry.

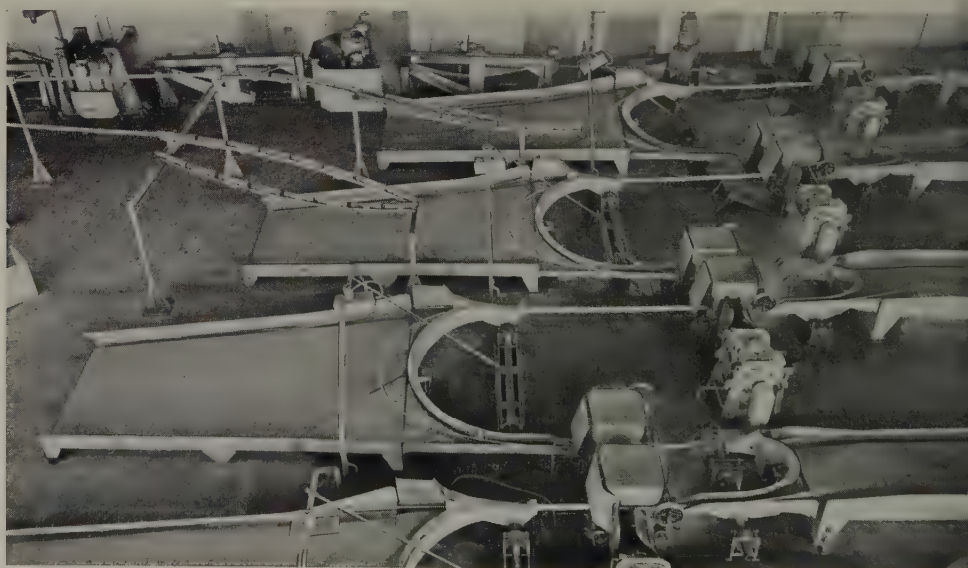


Fig. 6. Rolling rods in an alternating two-high rolling mill with horizontal loops. The photo-electric angular co-ordinate locators are mounted above the loops completely independent of the repeater tables. Soc. Nazionale Cogne, Aosta, Italy. (54516)

Asea Activities During 1959

The Asea Annual Report for 1959 shows that turnover continued to increase during the year. At the end of the year the number of employees in the Asea Concern was 10,900.

During the year, a certain proportion of the shares in three companies which were previously entirely owned by Asea was sold, with the result that Asea now owns less than 50 per cent of the shares in AB Svenska Fläktfabriken and in Svenska Turbin AB Ljungström (STAL), the Laval Ljungström Turbine Co.; on the other hand, Asea retains the majority of shares in AB Skandinaviska Verk. For further information on this subject please see Asea Journal 33(1960):1-2, p. 22.

THE PARENT COMPANY

As far as the activities of the Parent Company are concerned, the following may be worth noting:

Buildings and installations

Staff have started to move into the Melker office at Västerås. The new extension to the Sigurd factory has been taken into use. The lengthening of the assembly shops in the Emaus factory in an easterly direction is complete. In the Finnsletten area outside Västerås, a large factory has been started and it is intended con-

siderably to increase the manufacturing capacity for generators and other very heavy machines. Equipment is being installed in the new chemistry laboratory. A fifth storey has been added to the Arvid factory. At Ludvika, the new central heating plant, which also contains a 12,000 kW steam turbine belonging to Voxnans Kraft AB, is now in operation. The High-voltage Laboratory is being extended and an office building is being erected in conjunction with this work.

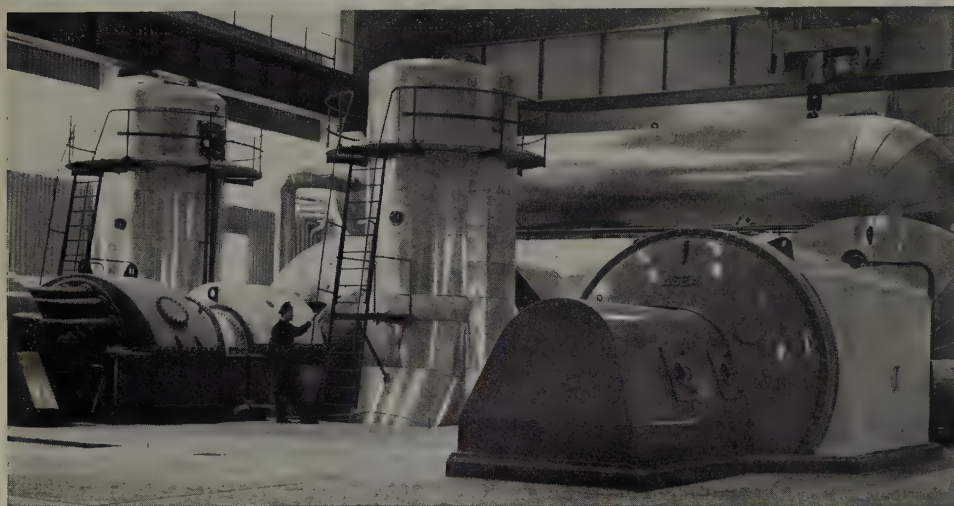
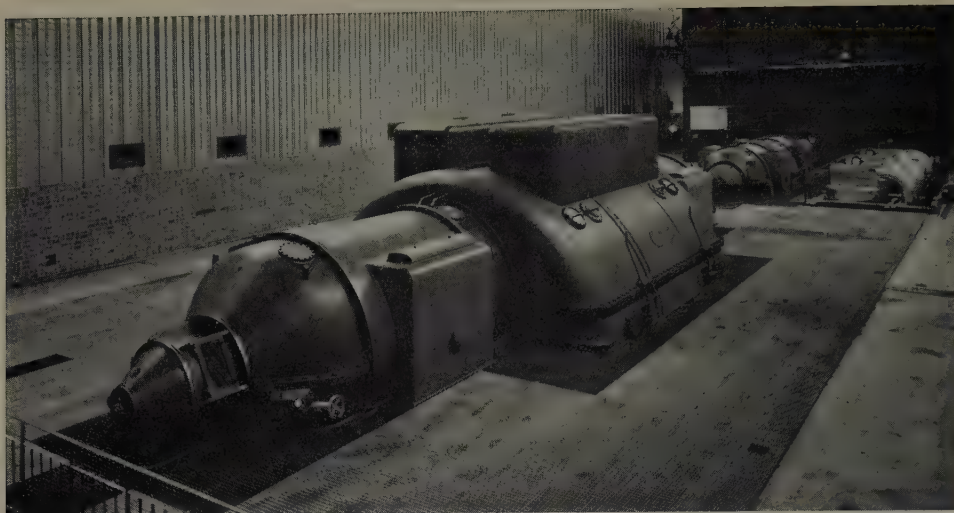
Market conditions

The recession which was noted during 1958 continued, as far as Asea were concerned, during the beginning of 1959. However, by May, orders were up to the 1958 level and later on in the year they considerably exceeded it so that there was, in fact, a considerable increase in the total of orders for the entire year. On the Swedish market, there was, almost throughout an increase in orders for industrial capital equipment. This was the case not least for mines and steelworks as well as for the cellulose and paper industries. On the other hand, there was a certain amount of restraint as far as investments by power producing and distributing companies

Turnover. In order to facilitate comparison between the various years, the turnover of those companies which were previously run on a commission basis have been subtracted from the turnover of the Parent Company. For the same reason, the turnover of the Laval Ljungström Turbine Co., AB Svenska Fläktfabriken and Asea Electric Ltd., London, has been subtracted from the turnover of the Concern.

Mill. Sw. Kr.





In conjunction with Asea de Laval Ljungstrom Turbine Co. has completed two remarkable orders for thermal power stations belonging to the Swedish State Power Board: a 150 MVA steam turbine installation at Stenungsund (upper illustration) and a 40 MVA gas turbine installation at Västervik (lower illustration). In each case, the generators are hydrogen-cooled. (54850, 54851)

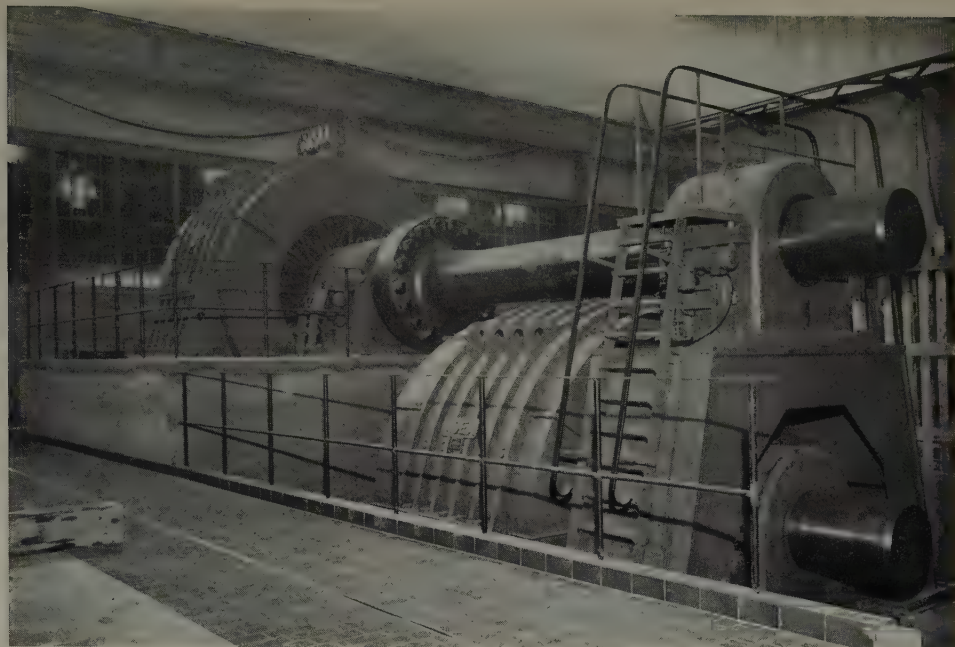
were concerned and these orders dropped somewhat below the 1958 level. The sales of stocked standard products rose considerably during 1959. The rising tendency on the world market brought in its train a considerable increase in orders from outside Sweden. This increase was mainly in special industrial equipment but also included standard products. However, as was the case on the Swedish market too, the sales of power-station equipment fell off. In all, export orders made up 25 per cent, and export deliveries 27 per cent, of the total orders and deliveries of the Asea Concern.

Technical development

Characteristic features of design developments were attempts to attain greater functional adaptation and reliability in service, reduced maintenance and lower manufacturing costs. Attempts were made to achieve these objectives by means of advanced methods of calculation, including the use of digital and analogue computers, the thorough reviewing of designs, searching for new materials, and adapting the designs to the practical demands of workshops and factories. Thanks to the experimental development of a new type of epoxy resin,

a method has been introduced for the coil insulation of large rotating machines resulting in improved machine characteristics. New manufacturing methods for products of glass-fibre-reinforced plastic have been worked out. Hydrogen-cooled turbo-generators have successfully been taken into service at the Västervik gas-turbine plant and at the Stenungsund steam power station, both belonging to the Swedish State Power Board. The cooling devices are based on many years of experience of hydrogen-cooled synchronous condensers which the company has made for ratings up to 100 MVA per set. New traction motors have been designed, both for single-phase alternating current and for rectified single-phase current, and silicon rectifiers have been installed on a test locomotive for the Swedish State Railways. During 1959 a new series of induction motors for the output range 150 – 1,500 h.p. and for voltages up to 6,600 V has been put into production. New synthetic insulating materials have been used in these motors, and since their fixing points have been moved from the stator to the bearing end shields, the basic design can be varied merely by the addition of simple accessories. The unconventional design of the motor is a result of co-operation

versible 360 ton-metre
iving machinery in a twin-
ive arrangement for the
eavy plate rolling mill
plied to Det Danske
aalvalseværk. Similar
iving machinery has been
uilt for Domnarfvets Jern-
erk and Oxelösunds Järn-
erks AB. (54854)



tion between the Company's electrical and industrial
esigners.

ewly designed transformers with dry-type insulation,
oth hermetically sealed and open, have been ordered
nd supplied to a considerable extent during 1959.

prototype of an 800 A, 100 kV ionic valve for the
c. transmission system across the English Channel
as been tested with very satisfactory results. The de-
velopment of silicon rectifiers for large outputs has led
to the type testing of a 200 A rectifier. Germanium and
silicon rectifiers have been introduced into various kinds
f regulating equipment, with a resultant saving of
pace and expenditure. In particular, mention can be
ade of a rectifier with controlled valves which was
plied to the Swedish Board of Telecommunications.

n the new High-power Laboratory at Ludvika, short-
ircuit tests with powers up to 2,500 MVA and voltages
ver 100 kV have been carried out, which figures can
e equalled by only a very few laboratories in the world.
he rational planning of the laboratory and its very
reat testing capacity have permitted the development
f new and improved types of high-voltage circuit-
breaker, thus enabling customers' demands for greater
reaking capacity to be met.

n new series of contactors rated at 10 – 100 A, with
ppropriate contactor starters, has gone into production
uring 1959. Characteristic features of the series are the
mall dimensions of the contactors and the accessibility
f all the vital parts. In the larger types, the live parts
e carried in a new thermo-setting plastic with glass-
ore reinforcement and particularly favourable dielectric
nd mechanical properties. This insulation material was
eveloped by Asea. The adoption of partially new manu-

facturing methods and the use of silver contacts and
certain wearing parts of nylon makes these contactors
suitable for the most exacting industrial tasks.

The development of box girders continues for cranes and
mine hoists. A new series of hoists has been designed
with lower weights and smaller dimensions than previ-
ously. By using a two-speed motor, the need for special
crawling machinery has been obviated.

The Asea high-vacuum melting furnaces commissioned
in the U.S.A., the first of their kind in the world,
represent a new and much appreciated technical aid in
the manufacture of high-alloy special steel for various
highly specialised uses.

An improved type of pressductor for measuring roll
pressures of thousands of tons has been designed. Its
dimensions are extremely small and the electrical equip-
ment very stable, rapid in action and free from voltage
pulsations. A new ring torductor for measuring torque
for use with shaft diameters up to 300 mm has also
been produced. The Company's activities in the elec-
tronics field are expanding rapidly. Several electronic
equipments for the controlling and automatisations of
industrial processes have been brought out, digital me-
thods being among those adopted.

The digital computer has mainly been used for solving
problems connected with atomic reactors and for the
systematic calculation of alternative design solutions for
new series of machines and transformers. The Com-
pany's analogue computer has been extended; it is used,
amongst other things, for studying the running proper-
ties of locomotives and rolling stock. The method de-
veloped jointly by the Swedish State Railways and
Asea for the continuous measuring of lateral rail forces

was worked out on the basis of these calculations, and was tried out in Switzerland, in 1959, under the auspices of an international railway research organisation; the results of these trials were very satisfactory. After about 2 years of thorough preparatory work, a programme has been drawn up for carrying out various routine office jobs by means of electronic data processing machines. At the beginning of 1960, an installation of this kind of the largest type was ordered from International Business Machines Co. (IBM). It is to be installed at Västerås.

Orders and deliveries

The Power-engineering Department has obtained orders for five hydro-electric generators with a combined rating of 455 MVA, from the Swedish State Power Board, for three generators rated at 16.5 MVA each from Bjurfors AB, and two generators rated at 10 MVA each from Sydsvenska Kraft AB. Additional orders have been received from New Zealand for a generator for each of two power stations to which Asea have previously supplied generators. An order has been received from Australia for a complete power-station equipment with two sets, each rated at 30 MVA. The Swedish State Power Board has ordered eight single-phase transformers rated at 400 kV. An order has been obtained from South Africa for two large three-phase transformers rated at 300 kV, and large orders for transformers have also been received from Australia, Poland and India. During the year, two 400 kV single-phase transformers rated at 333 MVA have been supplied to the Swedish State Power Board. The combined rating of the three-phase group will be 1,000 MVA, a new record for Asea which, as far as is known, has not been exceeded elsewhere in the world. In order to extend a 400 kV series-capacitor battery, the Swedish State Power Board has ordered capacitors for a combined rating of 53 MVar, and an order has been received from Italy for a 25 MVar series-capacitor installation. Export sales of high-voltage circuit-breakers and over-voltage protection have been at a high level. Incoming orders for instrument transformers and capacitors for voltage measurement have increased. In Australia, the first large power-station in the Snowy Mountains, Tumut No. 1, with four Asea generators each rated at 84.2 MVA, has been commissioned. A 120 MVA transformer supplied by Asea to Australia in 1959 is the largest transformer in the southern hemisphere. Work on the d.c. transmission scheme for the English Channel is continuing, and recognised type-tests on the equipment have been carried out in the presence of the representatives of the British and French customers. New Asea distance-protection equipment for high-voltage transmission lines has been purchased by customers in Sweden, New Zealand, South Africa and India. A modified design for use on electric railways has been

sold to British Railways. Remote-control equipments designed with new operating and metering systems which save channels have been sold to several power producing and distributing companies in Sweden and elsewhere.

The Industrial Department has received important orders for electrical equipment for large machines from paper and cellulose mills in Sweden and elsewhere. Orders have been received for drives and automatic control equipment for large high-speed printing presses from newspapers in Sweden and other countries. Orders from steelworks in Sweden, Finland and Belgium ensure continued increase in orders for electrical equipment for rolling mills. The sales of pressductors for measuring roll pressure etc. have now taken on considerable proportions and orders have been received from, amongst others, General Electric and Westinghouse in the U.S.A. Orders for arc furnaces and induction stirrers have been received from Swedish customers and from Norway, Holland, Germany, U.S.A. and Japan. A 3,500 lb (1,600 kg) high-frequency vacuum melting installation of the same type as has previously been supplied to the U.S.A. is to be supplied to a British customer. Orders for mains-frequency furnaces include two 25 ton units for heat holding and for the melting of cast iron, which are the largest of their kind in the world. A large number of complete mine hoists has been sold to firms in Sweden, Finland, Italy, Britain and South Africa. Important orders for overhead cranes have been received from Swedish steelworks, many of them for overhead cranes with a driver's cabin providing better vision and operating possibilities than the older types did. A number of overhead travelling cranes has been fitted with weighing devices built in accordance with the pressductor principle. The export of sugar centrifugals has developed favourably, and orders have been received from several European countries as well as, for example, from Australia, Mexico and South Africa. The Swedish Board of Telecommunications has ordered a considerable number of standby power plants and SAS have ordered about 20 newly designed ground power sets for aircraft. Sales of lifts and escalators have continued to increase and orders for high-speed lifts have been obtained. During the year, an agreement was reached with Westinghouse in the U.S.A., and the latter company is placing its experience in the field of lifts at Asea's disposal.

The Traction Department has received orders from the Swedish State Railways for complete electrical equipments for six experimental locomotives with a rating of 4,500 h.p. and a maximum speed of 120 km/h, and for eight express locomotives with a rating of 3,600 h.p. and a maximum speed of 150 km/h. Nydqvist & Holm AB, Trollhättan, have ordered generators and traction motors for 25 diesel-electric locomotives which are to be supplied to the Swedish State Railways. This latter

organisation has also purchased from Asea seven type 1A locomotives each rated at 5,400 h.p., a four-coach light-weight train set and a three-coach set for suburban traffic in Stockholm. Three three-coach light-weight train sets have been supplied to the Grängesberg-Oxelönd Railway. Further, in collaboration with AB Svenska Järnvägsverkstäderna, 32 coaches have been supplied to the Stockholm Underground Railways.

The Nuclear-power Department. The detailed designing of the R3/Adam project at Ågesta, where Asea is the main contractor, is continuing in collaboration with the customer, AB Atomenergi. The Swedish State Power Board has reached agreement with AB Atomenergi to the effect that the design work on the power-station reactor R4/Eva is to be concentrated on the pressurised heavy-water type, and Asea and Nydqvist & Holm AB have been entrusted with this work. In competition with firms outside Sweden, an order has been obtained from AB Atomenergi for a research reactor R2-0 for Studsvik. The production of sintered uranium oxide slugs for AB Atomenergi has started and equipment for the small-scale manufacture of canned fuel elements has been obtained. The experimental plant at Kvarntorp for the production of heavy water has been installed and commissioned in collaboration with AB Svenska Maskinerier. In co-operation with a British manufacturer, the planning work has been started on the rock-vessel reactor, which is similar to the British graphite-moderated type, but has a considerably higher working pressure which is made possible by locating it in solid rock with the rock taking up the pressure, in accordance with an Asea patent. A preliminary tender has been submitted for a complete installation having an electric output of 30 MW. Asea and Nydqvist & Holm AB have, through the agency of a company, AB Reaktorteknik, which they own in common, reached agreement with General Electric Company in the U.S.A. on the combined development of a detailed plan for a Swedish reactor of boiling water type.

ACTIVITIES OF THE MAIN SUBSIDIARY COMPANIES

Surahammars Bruks AB. Ore production in the company's own mines was on a smaller scale than in the previous year because of the reduced demand. Sales of pig iron and chills from Spännarhyttan increased. Sales and production at the steelworks in Surahammar increased. The new department for the manufacture of grain-oriented sheet steel at the steelworks at Surahammar was completed during the year. The running-in of the strip mill has continued and production has started.

AB Elektroheliös. The recession on the markets for electric cookers and heaters during 1958 was followed

by an upward movement during 1959 and orders received by the end of the year were considerably more numerous than the previous year. Among new items introduced during the year mention can be made of a stainless-steel sink unit with a built-in electric cooker, compressor-driven refrigerators with three temperature zones, a 250-litre deep-freeze, new refrigerators, smaller portable electric cookers, new electric hot plates, two new thermostat irons with light-alloy soles, a coffee-making machine designed in accordance with entirely new principles for use in restaurants, cafés and snack-bars, and new equipment for grill rooms. Exports increased considerably. The company's first foreign sales company has started its activities in Holland and has opened a modern salesroom in Rotterdam. Further, at the end of the year, a sales company was started in London.

AB Elektromekano. Orders increased in relation to 1958, particularly for standard motors. The orders received for transformers include a 93 MVA, and a 60 MVA, unit for the Swedish State Power Board and two 75 MVA, one 60 MVA, and five 42.5 MVA, units for export. During the year, six 60 MVA, 130 kV transformers were exported, as well as other items.

AB Liljeholmens Kabelfabrik. Turnover has increased. A new factory bay with an area of 3,600 m² has been erected. Major orders for the year include two high-voltage cables for India – an 8,000 m, 240 kV oil-filled cable and a 15,000 m, 30 kV compound cable. The Swedish State Power Board has ordered a 425 kV cable installation for Messaure power-station.

AB Asea Svetsmaskiner. Sales have increased throughout, the largest increase being on the export markets. Orders include equipment for the manufacture of heavy chain, three automatic welding machines of new type for the manufacture of light chain, about 15 flash welding machines for welding boiler tubes, a large pressure welding machine for the manufacture of refrigerator components and about 50 sets of welding tongs. There has been a considerable demand for the new arc welding transformer. A new basic high-yield electrode on a zirconium base has been put on to the market.

Subsidiary companies outside Sweden. The activities of these companies have, on the whole developed satisfactorily and the sales of products from Sweden have, in most cases, increased considerably above the 1958 level. Orders have also increased for products manufactured by the subsidiaries themselves. The extension of the transformer factory in São Paulo to twice its previous capacity was practically concluded during the year. During 1959, Asea Electric Inc., New York, opened a branch office in San Francisco. For the time being, the company is no longer represented in Greece.



This map shows places where the ASEA Group itself operates or is represented by agents. Because of limited space, only the headquarters of subsidiaries and representatives are shown. Through branch offices, and in other ways, ASEA is also represented in many other places. (Z 10692)

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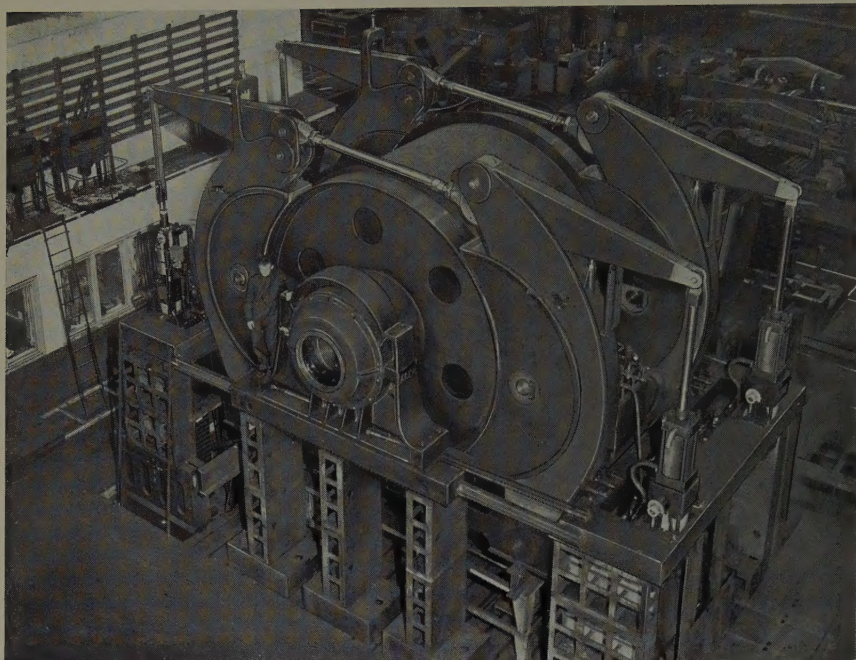
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NEWS IN BRIEF

EIGHT-ROPE FRICTION-DRIVE HOISTS FOR THE SOVIET UNION

Asea have recently supplied the Soviet Union with, amongst other items, two 4 m (13 ft) friction-drive hoists with eight ropes each. The illustration shows one of these being assembled in one of the Asea factories at Västerås.

The hoists, which are designed for the double skip hoisting of a useful load of 50 tons, a future hoisting speed of 14 m/s (45 ft/s) and a future depth of 1,300 m (4,300 ft), are probably the largest of their kind in the world. During the first stage of building, for a hoisting speed of 10 m/s (33 ft/s) and a depth of 950 m (3,100 ft), the motor output is 9,000 h.p. and in the final stage of development it will be 12,000 h.p.

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CONTENTS

The mains-frequency induction heating of light-alloy billets
by Y. Sundberg

Electronic aids for high-voltage tests
by L. Faxö

Loop regulation in rod and strip mills
by W. Bengtson

Asea's activities during 1959

The Asea Group throughout the World

News in brief

Eight-rope friction-drive hoists for the Soviet Union